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I.

CLIMATIC CHANGES IN THE ARCTIC IN RELATION TO PLANTS AND ANIMALS

PREFACE

By

GUNNAR ROLLEFSEN

THE complexity of many of nature's phenomena often makes it difficult for an investigator to obtain a survey of the conditions which may be of importance in nature.

Often we notice how one working theory is succeeded by another during the investigation of certain problems, and it is only natural that the sphere of interest and the personal qualifications of the individual investigator in many instances determine the importance he may attach to the different and possible causes of a certain phenomenon.

The individual investigator may also have his work impeded because the opportunities of exchanging ideas and experiences with other investigators, working in related fields of science, may be lacking.

From the discussions which have been going on for a long time on the fluctuations in the fisheries, we have seen clear examples illustrating such difficulties as mentioned above.

The causes of the fluctuations in the behaviour, occurrence, and abundance of fish stocks have been attributed to widely different conditions in nature, and practically no progress has been made on some of the problems for a very long time.

When the proposal of convening a Special Scientific Meeting on Climatic Changes was advanced, the idea behind it was to give investigators working on related problems, or whose work had resulted in the establishment of related working theories, an opportunity of acquiring knowledge of one another's work and views.

It was natural that the climatic changes in the Arctic and adjacent areas were chosen as the subject for the discussions on the meeting, because climatic changes might be expected to display more noticeable alterations in the composition of the fauna and flora of these regions than would be the case in more southerly areas.

During the preparations for the meeting endeavour was made to obtain the widest possible basis for the discussion by requesting investigators from different fields of science to submit contributions. An "Enquiry" was distributed in January 1948; its text is given as appendix.

It is to be hoped that these contributions in their printed edition may cause a further exchange of views between investigators interested in the problems, so that, perhaps at a later date, another meeting can be called for renewed discussions, a meeting to which those interested may come with an increased knowledge of this important field of research.

APPENDIX

Enquiry into the Problem of Climatic and Ecological Changes in Northern Waters etc.

At the meeting of the North-Western Area Committee of the "Conseil permanent International pour l'Exploration de la Mer" on October 22nd 1947 it was pointed out, that it would be of paramount interest for the fishery research work in the area, if the influence of the present climatic changes on the distribution, migrations, spawning conditions and density of marine animals could be studied, and it was recommended that every opportunity should be used, by fishery research vessels as well as by other ships, to carry out work especially in the waters north of the Faroes, north and east of Iceland and in the Denmark Strait and the Davis Strait. With relation to this very important question the Committee adopted the recommendation below.

"The problem of climatic changes in the Arctic being one of the most pressing problems in the Council's area, the collection of all possible relevant information should begin immediately, to avoid missing important information. In order to carry this out, it is proposed that the Chairmen of the North-Eastern and North-Western Area Committees be requested to act as editors of such material for the forthcoming year, and to submit a summary of the results at a Special Scientific Meeting of the next Council Meeting...

The Chairman should send through the Bureau requests to suitable bodies for information relevant to this subject, mentioning that short abstracts of information on terrestrial animals and plants would also be of interest."

This recommendation was adopted at the final Council Meeting on the 27th October.

Referring to the proposals mentioned we take the liberty to ask you to send us all particulars in your possession of interest. During this century many scientists, field ornithologists and people interested in natural history generally, have most likely had an opportunity to follow changes in abundance and distribution of several animals in a special area of the sea or land, and it will be of great interest to preserve these personal experiences for a future study of the important question: the relation between climatic changes and distribution of animals.

It is hardly necessary here to explain that contributions to our knowledge on this question may also have very far reaching economical importance—beyond the purely scientific interest. Thus it is clear, that some of the largest fisheries in the northern hemisphere—e. g. some cod fisheries —during the coming years will be completely dependent on the course of the present mild period in northern waters.

It is not possible in this enquiry to give in detail all items which may prove of interest, but we may mention some of obvious importance.

Reviews of *hydrographical*, *meteorological*, *glaciological* and other changes in various areas and the influence of these changes on *boundaries* (or breeding places) of marine animals and on *distribution* of terrestrial animals (mammals, birds etc.) and plants. Relevant faunistic records should be given with locality (longitude and latitude), depth (if marine records), date, observer etc., possibly with reference to papers, where such data are published. Especially important are: *new records of fishes*, crustaceans etc., from localities evidently but recently included in the range of distribution of such species, *changes in migration routes* and *spawning places*, *new breeding places* of birds farther north than hitherto observed, *wintering in northern areas* of normally birds; *disperson of mammals* towards the north in recent years, etc., etc. Also observations on *periodic changes in fecundity*, on *age at first maturity*, *growth rate*, *meristic characters* etc. may prove of very great interest.

Comparison of *variation in abundance of organisms* (fluctuations) over periods of years in a certain area may be available from various waters or countries, and should if possible be given for shorter periods as well as for longer periods of years. It has been pointed out that apparently there have been certain periods of years in northern areas with higher temperatures and simultaneously increasing occurrence of southern species, for instance in the years about 1820—30, 1840—50, 1870—80 and 1920—?. All data relating to such periodicities will certainly prove to be of great importance.

Changes in the Atlantic may be perceptible far south in the ocean, even to sub-tropic regions, and such records are of course of interest. Also observations on changes observed in *other oceans* besides the Atlantic or in *other continents* may be valuable.

It has been considered best to include collection of particulars relating to terrestrial animals and plants, hoping that such material may possibly show a certain correlation between these observations and certain climatic changes of evident influence on marine objects. This material should, however, also be dealt with by scientists interested only in relevant terrestrial problems.

Collection of observations will be continued during several years, but it is hoped that the present appeal will procure material for a long period back and encourage future observation work of great value.

All data ought to be given exhaustively, but in a concise and clear style facilitating collation of the several records.

The undersigned would moreover be very grateful for *abstracts or reprints of little known literature*, or references to notes and particulars in more or less easily accessible periodicals etc.

We request that the observations (if possible in typescript) be arranged under the following headings:

I. Meteorology. — II. Hydrography. — III. Glaciology, drift of ice etc. — IV. Animals: A. Mammalia (Cetacea, Pinnipedia etc.). B. Aves. C. Testudinata (e. g. observations off west coast of the British Isls.). D. Pisces. E. Invertebratae. — V. Plants. — VI. Other items.

Answers to this enquiry are requested to be submitted *not later than April 1st 1948* to the following address: Dr. Å. Vedel Tåning, Charlottenlund Slot, Charlottenlund, Denmark.

Observations obtained after April 1st 1948 may be submitted at your convenience, best during the month of December of each following year.

After use the material obtained through this enquiry will be preserved in the archives of the "Conseil permanent International pour l'Exploration de la Mer."

Kindly distribute surplus copies of this enquiry to people or institutions which might be interested in this special research work.

Gunnar Rollefsen.
Bergen.

Å. Vedel Tåning.
Copenhagen.

January 1948.

INTRODUCTORY ADDRESS

By

HANS W:SON AHLMANN

A result of the growing interest in most countries in the present climatic changes has been a rapid and continuing increase in the factual information available. This means, of course, that each new contribution to the subject is out of date almost as soon as it is written. Constant revision is therefore necessary.

One generally differentiates between climatic variation and climatic fluctuation, meaning by the former a change of climate maintained over a long period of time, and by the latter, a change over a shorter period. Climatic variations of primary importance are, e. g., the Ice Age glaciations with interglacial periods. Intermediate between variations of primary importance and fluctuations we have the climatic changes which have taken place since the last pleistocene glaciation, in post-glacial and historical times.

O. SELLING, in his doctor's thesis presented in September 1948, has shown that the general trend in the post-glacial climatological development of Scandinavia, as proved by paleo-botanical examination of peat bogs, has probably been the same as that of the Hawaiian islands. It may be mentioned that throughout the Bronze Age, Iron Age, and our so-called historical times the climatic curve has risen and fallen between eras unfavourable to man and others approaching the climatic splendour of the Stone Age.

According to C.-G. WENNER's doctor's thesis, presented in August 1948, proof of the same number of these smaller variations has also been found in Newfoundland. Labrador peat bogs indicate climatic changes there in the later part of post-glacial time which seem to have had the same main features as those in Scandinavia.

It seems therefore that the climatological variations and fluctuations after the last glaciation have been very extensive, possibly world wide.

A deterioration in the climate between A. D. 1200 and 1300 or a little later, is confirmed in Iceland by the variations in the glaciers. It is also probable that this climatic change has been an important factor in the final disappearence of the Nordic settlement in SW. Greenland, either as a result of a lowering of the temperature, or of a drying up of the climate, or of both factors.

It can be mentioned too that this climatic change (about A. D. 1300) coincides with the Mongol invasions from Central Asia westwards which have given rise to HUNTINGTON's well-known theories and all the discussions around them.

In more recent time the glaciers in Europe and in districts bordering the Northern Atlantic had a maximum extension in the latter part of the 18th or the beginning of the 19th century which must mean that at that time there was a climate more favourable for the glaciers, and consequently less favourable for man and most animals than at present.

I will now first touch upon some climatological investigations of special importance to the present problem. In 1940 A. WAGNER summarized the data relating to climatic changes in general, especially in historical times. He rejects the evidence of any regular periodicity—even BRÜCKNER's famous 35-year period—but he finds on the basis of comprehensive material that the climate in Europe and adjacent areas has improved in recent times.

The longest climatological series is from Holland from the beginning of the 18th century, published by A. LABRIJN. These records (see Fig. 1) show that the winter temperature—the uppermost curve—decreased from the first half of the 18th century to a minimum in the beginning of the 19th, after which there is an increase which continues up to the present. The hard winters during the 1940's depress the end of the curve. The lowermost curve, illustrating the difference be-

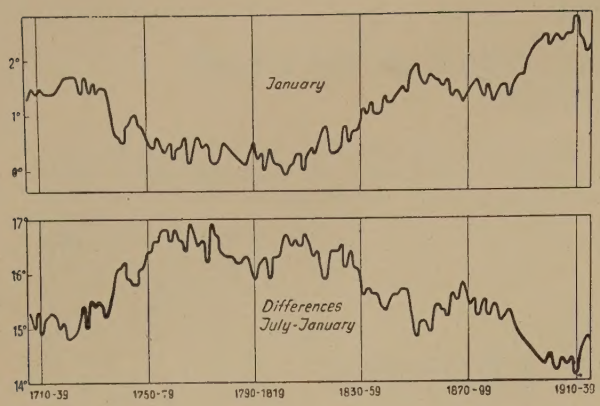

Figure 1. January mean temperature, and the difference between this and the July mean in Holland since the beginning of the 18th century. 30-year moving summations based on A. Labrijn's tables.

tween July and January, i. e., the degree of maritime or continental influence, is very significant in its decline from the end of the 18th century. The last few hard winters bend the end of the curve upwards.

The next longest series is by G. Manley from Lancashire covering the period since 1753 (see Fig. 2). The Stockholm records are treated by A. Ångström for the period 1760—1938. It is especially noteworthy that the general trend of the Stockholm curves is parallel with that of the Lancashire curves. The January temperature has risen about 1·7° in Lancashire and 2·5° in Stockholm, and the April temperature has risen a little over 1° in Stockholm. The autumn temperature has hardly changed at all, and the June temperature has even fallen a little. The annual mean has risen by 0·3° in Lancashire and 0° in Stockholm.

Th. Hesselberg and Birkeland's comprehensive analysis of the climatological statistics of Norway for the period 1816—1938 and of Spitsbergen for 1912—38 has shown the following facts: beginning in the 30 years interval 1836—65 the winter temperature has increased (compare Figure 3); the spring and autumn temperatures have risen somewhat less, while the summers show no distinct lasting changes until the interval 1902—31. The mean annual temperature has increased by 0·6° and the climate is becoming more maritime. The temperature rise increases considerably further inland and towards the north, reaching very high values in Spitsbergen, especially for the winters. In the last decade the summer temperature has also begun to rise in the Arctic. Hesselberg and Birkeland conclude with the statement that even though a steady change may be observed during the period 1864 to 1893, the increase in temperature in recent years is obviously by far the largest of any in the last 200 years.

(The changes in the temperature of Reykjavik were shown in a slide, summarizing Jon Eythorsson's results, and published in an Icelandic newspaper

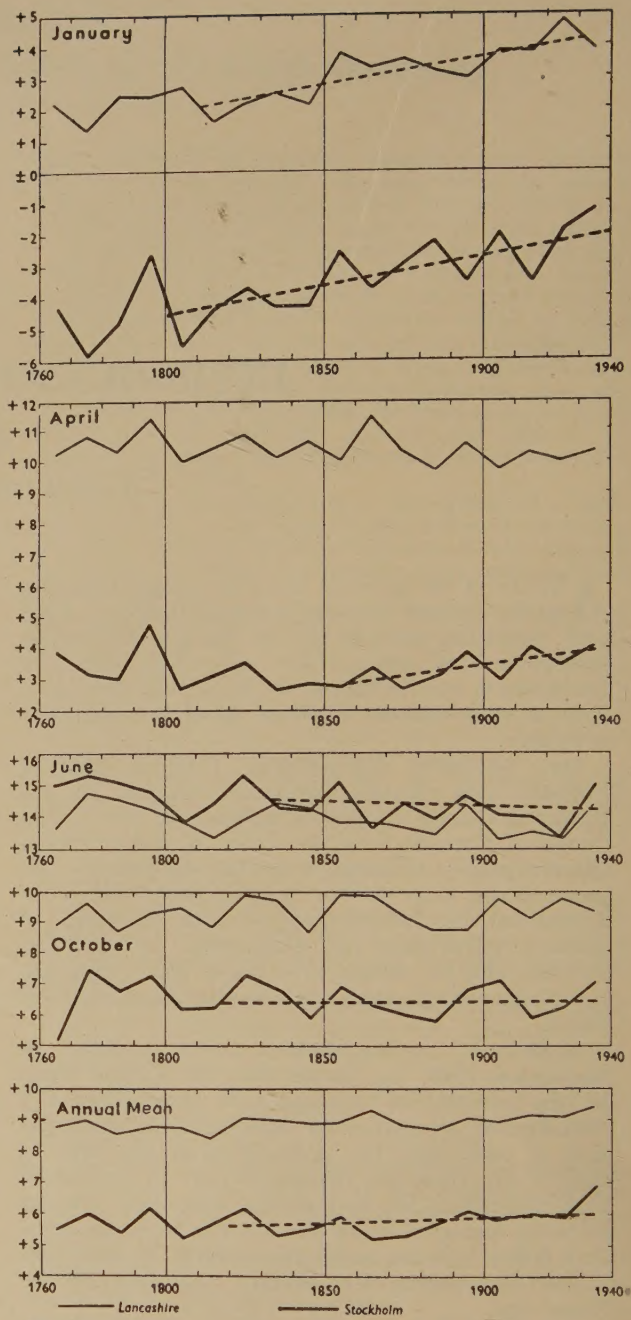

Figure 2. January, April, June, October, and annual mean temperature for the period 1760—1938 in Lancashire (upper curves) and Stockholm (lower curves). 10-year moving summations. After G. Manley and A. Ångström.

of 15th May, 1948, which unfortunately cannot be reproduced here.)

The recent climatic changes in Denmark have been studied by L. Lysgaard. It is not necessary for me to report his results here. It is, however, of special

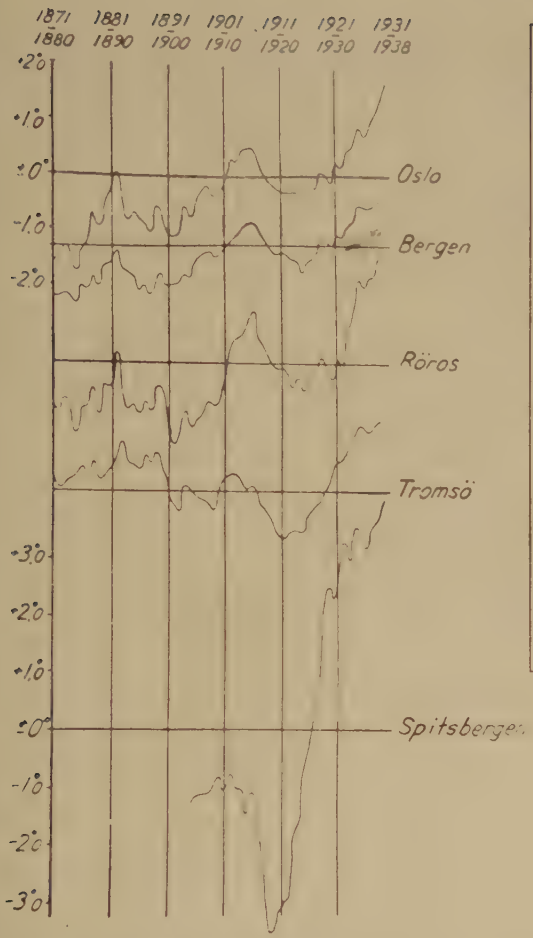

Figure 3. Mean winter temperature at stated places. 10-year moving summations. After TH. HESSELBERG and B. J. BIRKELAND.

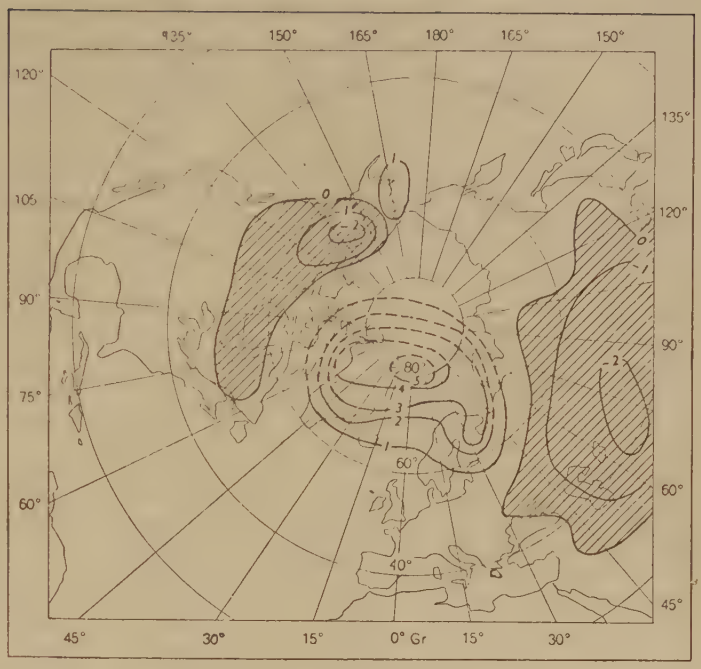

Figure 4. Deviation of the mean annual temperature in the Arctic in the period 1928—38 from the average for 1881—1938. After E. RUBINSTEIN.

interest that the difference in barometric pressure between Fanø in the southern part of Jutland and Skagen at its northernmost point has gone up 39% during the last 50 years and therefore the west and northwest winds over Denmark have shown a distinct increase.

Proceeding eastwards we first come to Finland. Prof. KERÄNEN says that it is now no longer possible to deny that the climate is improving, even though this is contrary to the thesis of the old meteorological school concerning the stability of the present climate. His investigations show that between the period 1899—1908 and 1929—38 the temperature has risen by 1·7° to 2·7° in all seasons. Of special importance, particularly to agriculture and forestry, is the lengthening of the period of vegetation.

A sensitive measure of variations in the climate, particularly of the temperature in Finland as well as the Baltic region as a whole, is the extension of the ice at the coasts. R. JURVA has shown that the secular change as regards this phenomenon during the period 1830 to 1940 is a continuous decrease of the ice from 250,000 sq. km. at the beginning of the period to 180,000 at the end. The most remarkable period was that of the 1930's which were exceptionally ice-poor years. In the 1940's on the contrary the winters have been exceptionally rich in ice.

As regards the U.S.S.R. L. RUBINSTEIN has published a climatological study of her country. From her diagrams it appears that an increase in the winter temperature began in about the latter part of the 19th century, and that it was especially marked at such far northern stations as Kola, Archangel and Leningrad while no increase was noticeable, for example at Kiev.

From RUBINSTEIN's paper with drawings illustrating the difference between the temperature in January, February, March and April 1929—38 and the average for the period 1881—1938 for the whole Arctic it is seen that the greatest positive anomalies are to be found in January and February. During the latter month we find the values + 5° and + 6° from West Greenland to Spitsbergen. The whole Arctic lies inside the + 1° line. (According to these maps the temperature improvement does not spread over most parts of Europe, the easternmost Arctic and Asia, and the northern Pacific Ocean. One must however remember that the records from many parts of these districts are scanty and not of the highest quality.) Figure 4 shows the deviation of the mean

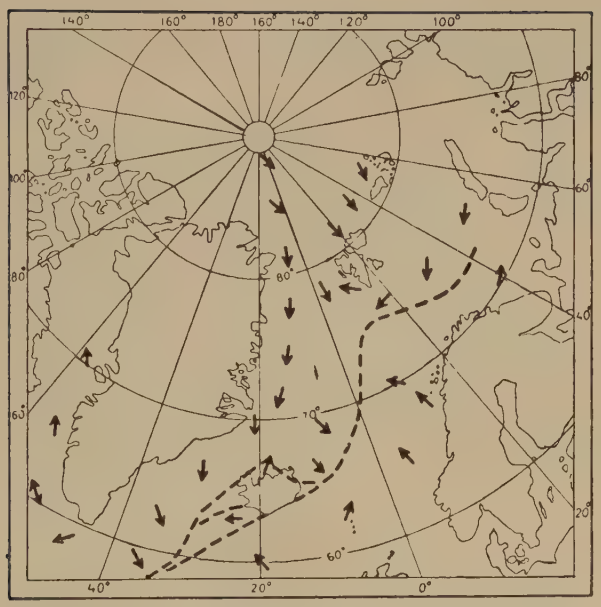

Figure 5. Wind convergence derived from the directions of the prevailing surface sea currents. After Backa E. Eriksson.

annual temperature in the Arctic in the period 1928—38 from the average for 1881—1939.

It can also be mentioned that the present rapid sinking of the surface of the Caspian Sea is probably due to a climatic change with increasing dryness in the drainage areas of the Kama and central Volga. It is reported further that the annual evaporation from the Caspian Sea is calculated to be 15,000 million m.³, while the Volga's water-supply is only 3,000 million m³.

As to the meteorological reason for this very remarkable climatic change in the arctic and the subarctic regions, it appears to be caused by an increased atmospheric circulation or increased transfer of heat from low to high latitudes. This theory has been confirmed by Backa-Eriksson's analysis of barometric pressures, winds, and drift ice, in the northernmost Atlantic. According to him, it seems that the immediate cause of the general improvement of the climate in these regions has been a general intensification of the atmospheric pressure gradient, resulting in increased supplies of warm air. His investigations have also demonstrated that while the mean atmospheric winter pressure has been considerably reduced, the summer pressure has generally remained the same or—in certain districts of Norway—even increased slightly. Hence an extra southerly wind component has been superimposed on the mean wind of 1901—1930, which has resulted in an increased transport of heat. The location of the maximum increase in the temperature in the far north, is explained by the fact that the low pressure area in the North Atlantic has moved abnormally far to the north, thereby changing the direction of the atmospheric pressure gradient so as to increase the flow of warm air to these arctic regions. The climatic change has thus obviously been associated with changes in the directions and forces of the winds. This is one of the chief reasons for the good pack-ice conditions observed in recent decades in this part of the Atlantic as well as in the arctic waters of the Soviet Union.

If we turn to North America we can recognize many facts similar to those in Europe. For example, the temperature in Philadelphia and New Haven, Conn., has increased since the middle of the 19th century, the evaporation in Colorado has increased, the level of the Great Salt Lake has fallen 16—17 feet since 1875, the precipitation in Baltimore and Boston and the percentage growth of the tree-rings has decreased. For other examples I refer to Tannehill's book "Drought".

In *Nature* for March 1948 Mr. L. Lysgaard gives a short account of his investigations of temperature and precipitation for the whole earth, in which he compares conditions during the period 1881 to 1910 with those for the period 1911 to 1940. (At the meeting of the International Union of Geodesy and Geophysics in Oslo in August 1948 Mr. Lysgaard also gave a summary of his investigations in the form of a series of maps. He showed that "over great parts of the earth, especially in temperate and arctic zones, both winter and summer temperatures seem to have been subjected to an appreciable increase, while over other parts, especially in the tropical and sub-tropical zones, a decrease in temperature has taken place. Also an increase in rainfall is recorded over great parts of the temperate and arctic zones and over the monsoon regions of south-east Asia, while a decrease is recorded over other tropical and sub-tropical

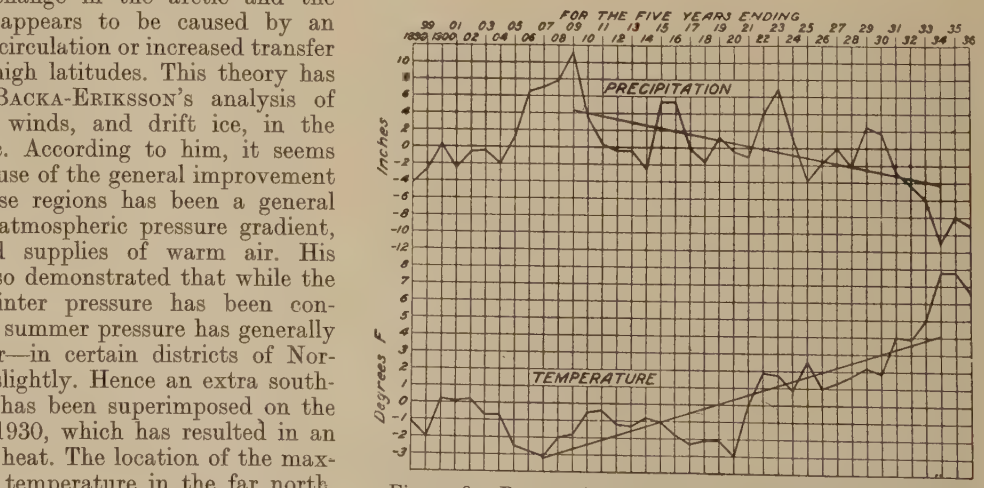

Figure 6. Progressive 5-year sums of temperature and precipitation departures from the normal for the United States. After J. B. Kincer and I. R. Tannehill.

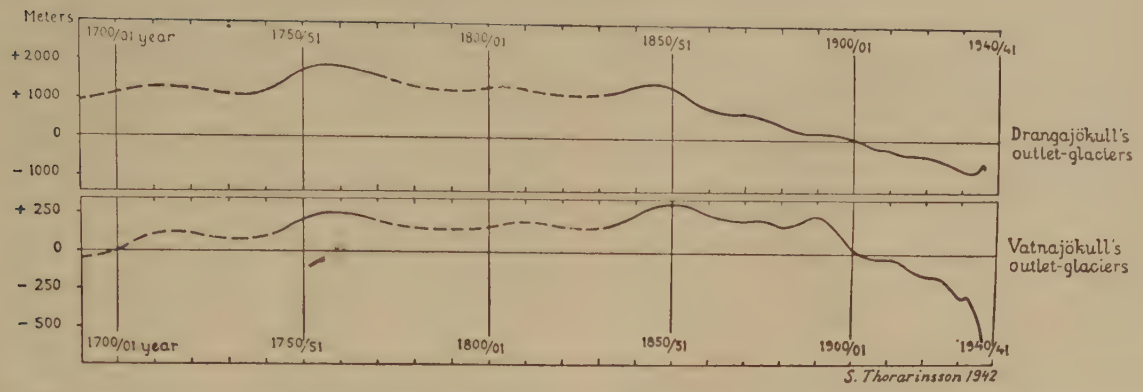

Figure 7. Approximate curves showing the oscillations of the Drangajökull outlet-glaciers and the southern outlet-glaciers of Vatnajökull in Iceland. After Sigurdur Thorarinsson.

regions, such as Africa, Australia, Brazil and the United States".)

However, there still remains extensive work to be done before one can with certainty make a statement about the total extension of the present climatic fluctuation and its causes. It is, however, in fact the first climatic change in the endless series of past and present climatic variations in the history of the earth which we can measure, investigate and possibly also explain. To my mind the importance of this fact cannot be exaggerated.

Even if it seems that the present climatic fluctuation involves a great part of the earth it is of the greatest importance to the whole problem to discover whether it has manifested itself in other ways and thus produced confirmatory evidence. This is the more desirable as nearly all temperature records are to some extent artificial, since they are taken within screens at fixed heights above the ground.

We will therefore look first at glaciers as they are very sensitive registers of changes in temperature and precipitation.

After studying the glaciological literature about glacier variations, the Icelander Sigurdur Thorarinsson has come to the following conclusion: "the marginal variations of the glaciers in recent centuries have in all probability been more or less concurrent all over the world." The majority of the glaciers in practically every glacier district of the world—outside the Antarctic of which we know nothing with certainty—are now receding.

Briefly summarizing the results of the investigations of the glacier's material balances or budgets and their variations in the North Atlantic area we can say:

1) All glaciers examined round the northernmost Atlantic are shrinking. The decreasing thickness of the glaciers has been of greater importance than the recession of their margins. The decline of the ice has increased during the last decades. This reduction of the glacier volume stands out as the hitherto last stage in a shrinkage, which began about 200 years ago when the local glaciers reached their maximum extension in historical time, perhaps even in post-glacial time. Some glaciers have declined to such a degree that their existence is in danger if the present conditions continue with the same intensity in the coming decades. Already some small glaciers have disappeared.

2) All the glaciers in recession have a strong negative budget, i. e., the glaciers lose more material by ablation than they receive by accumulation.

3) The temperature has at present a greater effect on the regime than the precipitation, especially by lengthening the ablation season.

4) The reason for the glacier shrinkage seems to be an increasing convection or transport of heat by the atmosphere and a lengthening of the melting season in spring and autumn. Thus, these results agree very well with the meteorological evidence.

To illustrate these general conclusions I will mention here a few specific cases.

Icelandic glaciers have had two maximum extensions, the first during the middle of the 18th century, the second one hundred years later. Since the end of the 19th century the Vatnajökull outlet-glaciers have been retreating at gradually increasing rates, even during the last few years. (Fig. 7.)

The same conditions are found in Norway. The outlets of the vast Jostedal ice-cap in South Norway reached their maximum extension after the Ice Age about the middle of the 18th century. Since then they have been in recession, interrupted, however, by smaller advances over some decades. Since 1910 their total recession has been 490 m. (Fig. 8), which means that some of these outlet-glaciers have completely disappeared or are reduced to but a fraction of their former size.

During the last few years the snow or firn limit on most Norwegian glaciers has risen above their highest parts, so the glaciers are living only on their own mass without receiving any annual fresh supply of snow.

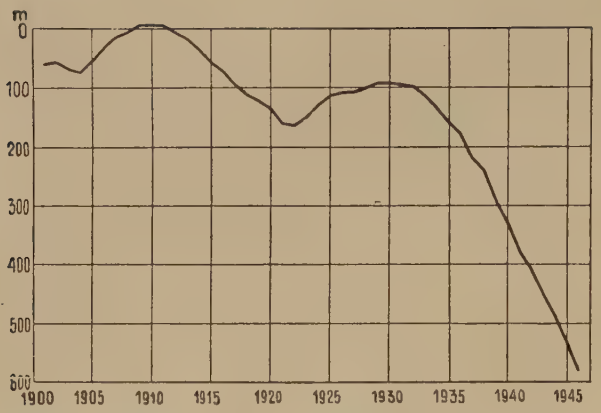

Figure 8. Frontal variation of the Jostedalsbre outlet-glaciers in Norway, average values of observations on 10—15 glaciers by J. Rekstad, and later by K. Faegri.

The discovery of arrows with their wooden shafts and in some cases even their feather vanes on the surface of vanishing snow-patches in the mountains of Central Norway has led K. Faegri in Bergen to the probably correct conclusion that the snow cover there in the 1930's was less than in any other period since the time of these arrows, e. g., the migration period about 1,400 to 1,500 years ago.

The Swedish glaciers show much the same development as those in Norway. The Stor Glacier (3·3 km²) in Kebnekajse Massif in Lapland has been for three years now the object of systematic investigations as the Scandinavian base in an international network of glaciological research, which is being carried along on similar and coordinated lines. The glacier has, between 1922 and 1946, decreased in volume by about 70 mill. m³., an average of 0·8 mill. m³. per year, per km². The net loss of the glacier increased in the budget year 1946—47 to 1·9 mill. m³. per sq. km., a ruinously high figure. In the last budget year 1947—48, closed last September, the regime of the glacier has been balanced, due to much snow in the winter and a cold, rainy summer.

In the Alps there has been a glacier retreat and shrinkage during the last decades, which was catastrophic during the summer 1947. According to a report of the firn region of the Aletsch Glacier, presented by R. Haefeli and P. Kasser at the Oslo Meeting last August, the glacier surface has dropped by about 2—4 dm. a year in the period 1851 to 1926 and by about 7—10 dm. a year from 1926 to 1947.

All the facts about glacier shrinkage in Europe seem to be eclipsed by what has taken place in Alaska. Muir Glacier in Glacier Bay receded about $10^1/_2$ km. from 1935 to 1947 with a lowering of the ice surface at the latter position of some 300 m. (Fig. 9.) The open fiord district has been increased in area by no less than 15·5 sq. km. in this 13 years period. Most of the glaciers in Alaska are now receding from terminal moraines formed during a period of maximum advance in the eighteenth and nineteenth centuries.

The summer temperature in the period 1935 to 1946 was higher than normal and though the total annual precipitation increased the amount of annual snowfall decreased.

Turning to glacier variations and other climatic fluctuations in low latitudes I will remind you that the present-day changes in East Africa are indicated, like earlier ones, by fluctuations of the glaciers on the highest mountains and by the changes of level of the lakes without outlets in the Rift Valley. The glaciers on the three East African high volcanos have been diminishing since they were first investigated in the 1800's. Since 1920 this decline has proceeded more rapidly than before. During the last 30 years the levels of the lakes have also shown a very marked lowering; that of Lake Victoria has fallen about 7 ft. during the last 10 years. Lake Nakuru is completely dried up and Lake Naivasha in the neighbourhood of Nairobi, which had a low water level up to 1882

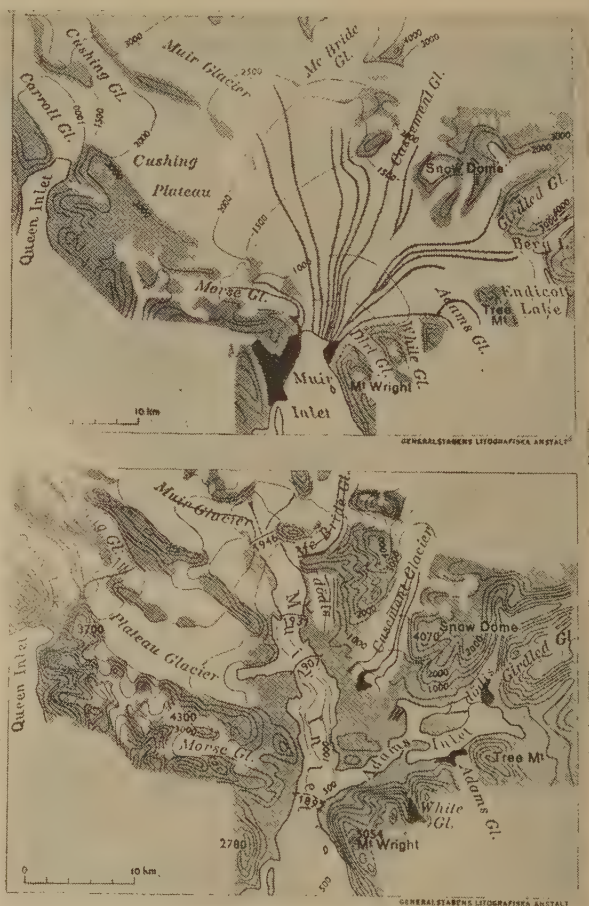

Figure 9. Recession of the glaciers in Muir Inlet, Glacier Bay, Alaska. The upper picture from 1892, the lower from 1946. Heights in feet above sea level. After W. O. Field, jr. and C. Mannerfelt.

followed by a rise, has been rapidly falling again since 1917, simultaneously with a serious decrease in precipitation.

The decrease in water over vast areas of Africa has been taking place for a long time, and according to E. P. Stebbing the Sahara has encroached southwards during the last centuries with a mean speed of 1 km. per year.

Short reports, not yet published, sent in from Peru, Colombia and Argentina to the Oslo meeting, speak of glacial recession in the Andes.

The same can be said about the glaciers in the high mountains of Central Asia.

S. Thorarinsson's conclusion about the world-wide retreat of the glaciers based on literature available in 1940 can now be strengthened by saying: the glacier recession has continued; in many districts, especially in those round the northernmost Atlantic, it has strongly increased.

The hypothesis of an increasing atmospheric circulation over the northern Atlantic leads one to expect changes also in the sea as regards its currents, temperature, salinity etc. I entrust to the present oceanographers to account for these phenomena.

As a result of the warming of the sea water and of the increasing air temperature, the thickness of the ice forming annually in the Polar Sea has diminished from the Nansen "Fram" expedition of 1893—96, when it was at an average of 365 cm., to 218 cm. during the drift of the Russian icebreaker "Sedov" in 1937—40. The extent of the pack ice in arctic waters has also diminished considerably in the last decades. The shipping season for the coal-fields in W. Spitsbergen has lengthened from three months at the beginning of this century to about seven months during the last few years.

According to personal information received at the Arctic Institute in Leningrad in June 1945, ice conditions began to improve in the Barents and Kara Seas in 1920, and the improvement has since been gradually extending further eastwards. On the basis of charts of the extent of the drift ice in the Russian sector of the Arctic, constructed from air photographs, taken in all the light months of the year, it has been found that from 1924 to 1944 the drift ice was reduced by no less than 1,000,000 km^2.

It may also be mentioned that a couple of fossil ice-islands in the Leptev Sea have melted away completely, leaving only submarine shoals behind. Of no less practical importance to Russia is that the southern boundary of the perennially frozen earth in Sibiria has receded considerably in the last decades.

Also the time with pack ice on the northern coast of Iceland has diminished in length, by about 2 months from 1861—1890 to 1911—1940.

Another result of these altered conditions in the sea is that various kinds of fish and other sea animals and plants have migrated further northward. The biologists have much to say about these conditions.

A great economic benefit derived from the improved climate will also be an increased vegetation growth. An increasing cultivation of oats has occurred in Iceland. In Norway, with the exception of the innermost districts of the Sognefjord where the temperature does not show the same increase as in the rest of the country, the cultivation has ascended during recent decades. Improved prospects of agriculture have occurred in the northern parts of Sweden and Finland, not only due to better seed and improved cultivating methods but also to the lengthening of the vegetation period. In the forests of northern Scandinavia the economic benefits are of special significance. The trees spread rapidly above their previous timber lines and the annual rings of both pine and spruce show a quicker growth than for about two decades. Another significant fact is that while the northernmost part of Norway, Finnmark, had only two seed years of importance in the 40 years between 1875 and 1915, good seed years now appear with few interruptions. I. Hustich, one of the first men who observed and investigated the influence of the present climatic fluctuation on forest conditions, shows in his last publication of 1948 that the radial growth of the pines at the timber line in the extreme north of Finland, at about 69°30′—70° N., had an obvious "low" period in 1901—16 after which an improvement has occurred. The "low" period coincided with relatively bad seed years and a regression of the timber line, the "high" period with increased July and August temperatures, relatively good seed years and an advance of the timber line.

From Alaska R. Griggs points out that "everything .... suggested that instead of being held to a stationary line the forest is advancing".

It is also of interest to notice that in the south of Sweden as well as in Germany and Switzerland the growth in height of raised bogs has temporarily ceased and a new so-called recurrence or heath layer seems to be formed as a result of the present climatic fluctuation. C.-G. Wenner has found the same in Newfoundland and Labrador.

Finally I will touch on a more universal phenomenon. As you must know, the storing of water in the ice sheets during the last glaciation lowered the surface of the oceans. During the recession of the ice the melt-water drained into the oceans increasing their volume and raising their surface levels. Sigurdur Thorarinsson has pointed out that the losses of the glaciers during the present climatic fluctuation must also have raised the sea level. That this is so, is proved by B. Gutenberg's analysis of records from gauges, or mareographs, in different parts of the world, which indicates that the rise during the last decades has been in the order of 1 mm. per annum.

In his renewed examination of the data for the period 1890 to 1944 taken from the recording gauge stations along the Danish coasts, J. Egedal also discusses the influence of the eustatic variation of the sea level, and he comes to the conclusion that it may be supposed that the mean eustatic variation in that period has been positive and that it does not essentially exceed 0·5 mm. per year.

This relatively small value (0·5—1 mm. per year) indicates that the Antarctic and the main part of the Greenland inland ice—together containing more than 90% of all present ice covers—cannot have decreased at the same rate as the local glaciers examined. If these inland ice sheets should begin to melt as rapidly as the other glaciers the rising sea level would become a far-reaching phenomenon of great practical importance.

It appears from what is stated that the polar regions and especially the Antarctic occupy an important position as a field of investigation concerning the present climatic fluctuation. We hope that the Norwegian-Swedish-British expedition, which will start next autumn to Queen Maud Land, would be able to contribute effectively to elucidating the problem.

I also hope that this short review of some phenomena relating to the present climatic fluctuation has proved its very great importance both from theoretical and practical viewpoints.

DISCUSSION

A. CONTRIBUTIONS ON PHYSICAL CHANGES

1.

Recent Climatic Fluctuations.

By

Leo Lysgaard

Climatic fluctuations may occur in many forms. For example, over a period the mild winters may have become milder and more frequent or the severe winters less severe and less frequent.

Table 1 shows the maximum negative and positive deviations from the mean temperature of the past 150 years, $T_{(1798-1947)}$ for Copenhagen for January, February, July, August and the whole year for the periods 1798—1827, 1828—57, 1858—87, 1888—1917 and 1918—47.

Table 1. The maximum negative and positive deviations from $T_{(1798-1947)}$, Copenhagen.

Period	1798–1827	1828–57	1858–87	1888–1917	1918–47
January ..	—5·4	—4·6	—3·9	**—6·2**	—5·9
	3·4	2·5	3·9	3·8	**4·2**
February .	—6·0	**—7·2**	—4·1	—5·6	—6·1
	4·0	2·1	3·6	3·7	**4·4**
July	—3·5	**—4·0**	—2·8	—2·8	—1·4
	3·7	3·4	1·7	3·3	2·9
August ...	—1·5	—2·9	**—3·7**	—3·2	—2·3
	4·1	**4·2**	2·5	1·8	3·3
Year	—1·3	**—2·4**	—1·7	—1·1	—1·2
	1·9	1·3	1·0	1·3	**2·2**

The mild winters have been milder, while the severe winters seem to have remained severe. The warm summers were less warm in the periods 1858—87 (July) and 1888—1917 (August), while the cool summers have been less cool since the periods 1828—57 (July) and 1858—87 (August). The cold years have been less cold since the period 1828—57, and the warm years warmer since 1858—87.

Table 2 shows the numbers of the cold, the normal and the warm months and years in the same 5 periods.

The severe winters seem to have been less frequent, but the mild winters more frequent since the period 1828—57. The cool summers have been less frequent since the same period, but the warm summers more frequent since 1858—87.

Apart from the very severe winters the temperature seems to have been higher in winter, because the number of winter months with negative deviations has decreased from 34 (period 1828—57) to 20 (period 1918—47), at the same time as the number of months with positive deviations has increased from 24 (period 1828—57) to 40 (period 1918—47). Apart from the very warm summers the temperature seems also to have been higher in summer, because the number of summer months with negative deviations seems to have decreased from 37 (1828—57) to 19 (1918—47), at the same time as the number of months with positive deviations has increased from 22 to 39. Similarly the number of years with negative deviations has decreased from 19 to 9, while the number of years with positive deviations has increased from 8 to 21 (from period 1828—57 to period 1918—47).

Similar results are found for Oslo, Stockholm, Helsingfors, Berlin, Amsterdam, London, New York and so on.

Fig. 1 shows the fluctuations in the temperature (Normaltemperaturen, C°) and the precipitation

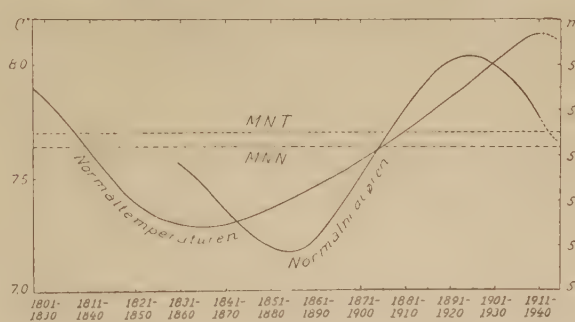

Figure 1. Fluctuations in temperature and precipitation, 1801—1945. Normal temperature. Normal precipitation.

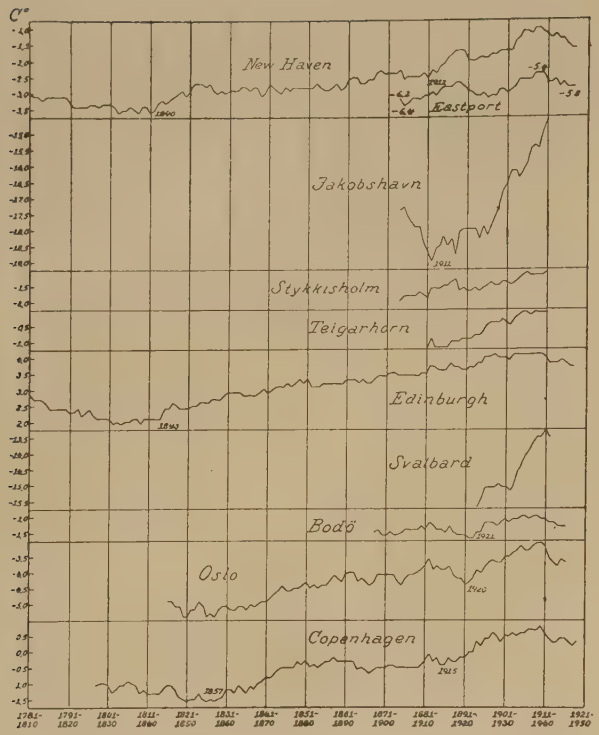

Figure 2. The variation in the temperature, 1781—1947.

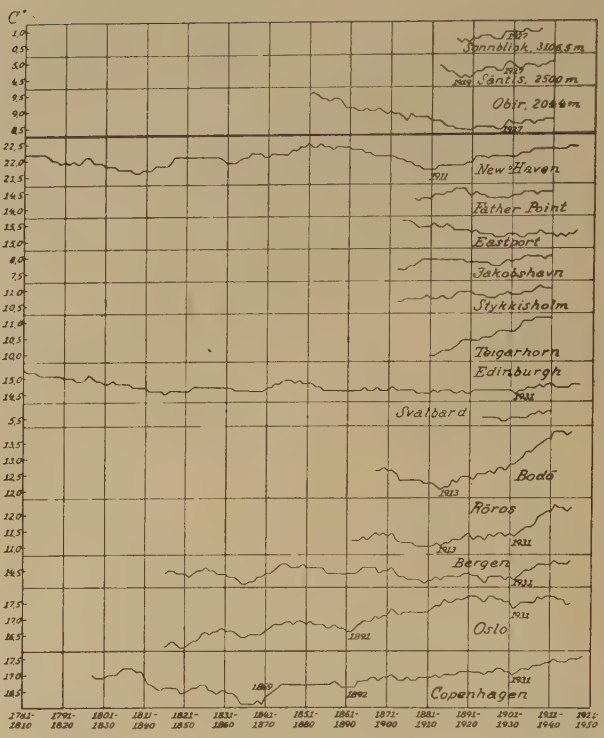

Figure 3. The variation in the normals of temperature, 1781—1947.

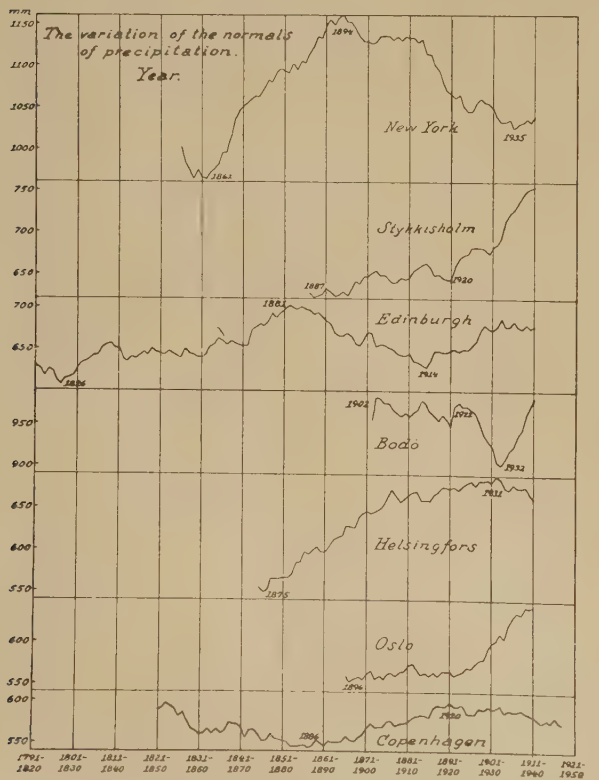

Figure 4. The variation in the normals of precipitation, 1791—1947.

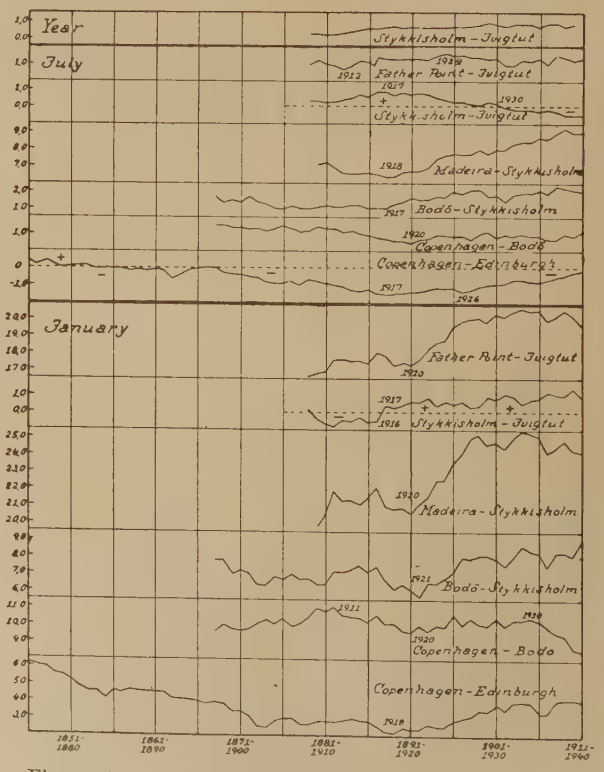

Figure 5. The variation in the normals of pressure differences, 1847—1940.

Figure 6.

Figure 7.

Table 2. The numbers of the cold, the normal and the warm months and years in the five periods. The distribution of the cold, normal and warm months and years.

Deviation		Period 1798–1827	1828–57	1858–87	1888–1917	1918–47
January..	—2·5 — —6·2	**7**	6	5	2	3
	—1·5 — —6·2	**11**	9	6	4	6
	0·0 — —6·2	16	**21**	13	10	10
	0·0	**1**	0	0	**1**	0
	0·0 — 4·2	13	9	17	19	**20**
	1·5 — 4·2	8	3	8	7	**12**
	2·5 — 4·2	4	1	5	3	**9**
February.	—2·5 — —7·2	4	**8**	3	3	4
	—1·5 — —7·2	**9**	**9**	**9**	8	6
	0·0 — —7·2	12	**13**	10	12	10
	0·0	**3**	2	0	0	0
	0·0 — 4·4	15	15	**20**	18	**20**
	1·5 — 4·4	10	5	**12**	10	**12**
	2·5 — 4·4	4	0	7	2	**9**
January and February	—2·5 — —7·2	11	**14**	8	5	7
	—1·5 — —7·2	**20**	18	15	12	12
	0·0 — —7·2	28	**34**	23	22	20
	0·0	**4**	2	0	1	0
	0·0 — 4·4	28	24	37	37	**40**
	1·5 — 4·4	18	8	20	17	**24**
	2·5 — 4·4	8	1	12	5	**18**

Deviation		Period 1708–1827	1828–57	1858–87	1888–1917	1918–47
July.....	—2·5 — —4·0	2	**4**	2	1	0
	—1·5 — —4·0	6	**9**	4	5	0
	0·0 — —4·0	14	**19**	13	14	8
	0·0	1	0	**2**	0	0
	0·0 — 3·7	15	11	15	16	**22**
	1·5 — 3·7	6	3	1	5	**8**
	2·5 — 3·7	**2**	**2**	0	**2**	1
August...	—2·5 — —3·7	0	**4**	1	1	0
	—1·5 — —3·7	1	**7**	6	5	3
	0·0 — —3·7	13	18	**22**	20	11
	0·0	0	1	0	0	**2**
	0·0 — 4·2	**17**	11	8	10	**17**
	1·5 — 4·2	**7**	**7**	1	2	6
	2·5 — 4·2	**5**	4	1	0	3
July and August	—2·5 — —4·0	2	**8**	3	2	0
	—1·5 — —4·0	7	**16**	11	9	3
	0·0 — —4·0	27	**37**	35	34	19
	0·0	0	1	**2**	0	**2**
	0·0 — 4·2	32	22	23	26	**39**
	1·5 — 4·2	13	10	2	7	**14**
	2·5 — 4·2	**7**	6	1	2	4
Year.....	—1·0 — —2·4	5	**7**	6	2	2
	0·0 — —2·4	12	**19**	18	11	9
	0·0	2	**3**	2	2	0
	0·0 — 2·2	16	8	10	17	**21**
	1·0 — 2·2	7	1	1	2	**10**

(Normalnedbøren, mm.) for the year at Copenhagen. MNT and MNN are the long-range normals of temperature and precipitation.

Figs. 2, 3, 4 and 5 show the fluctuations in the temperature, the precipitation, and the pressure difference.

The increase in temperature is greatest in the arctic regions. It is remarkable that the temperature has risen in July as well as in January at most of the stations during recent years. The curves of Fig. 4 have a different shape because the precipitation is very variable. The pressure difference (also the gradient and the circulation) has increased since 1915. It is very interesting that the January normal of pressure difference (Stykkisholm—Ivigtut) became positive between 1911 and 1920. At the same time the air temperature of Greenland as well as the water temperature increased and the cod arrived in the seas off Greenland.

Figs. 6, 7, 8, 9 and 10 show the variations in

Figure 8.

Figure 9.

Figure 10.

temperature, precipitation and pressure from the period 1881—1910 to the period 1911—40 for the whole world. The arctic regions show the largest increase in temperature in January, but Fennoscandia and U.S.A. in July. The precipitation has increased in the arctic and temperate zones and also in the monsoon regions at the Philippine Islands, but has decreased in the U.S.A., West Africa and Australia. The pressure has a maximum decrease in Ireland in January and in Spain in July. It seems that the pressure has increased over the continents in winter and over the oceans in summer, but has decreased over the continents in summer and over the oceans in winter.

The curves and maps do not tell us if the climatic variation is a fluctuation or a change of a more permanent nature.

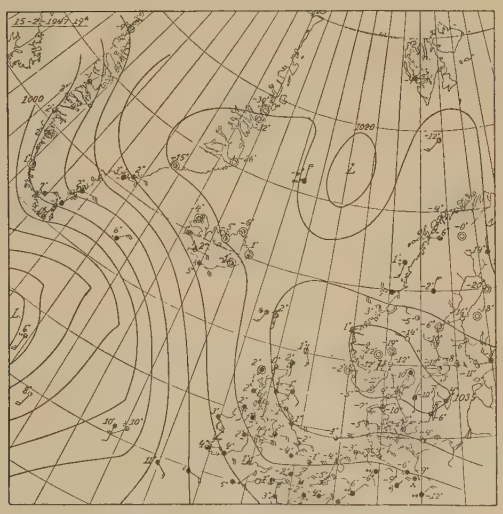

Figure 11. Europe, severe; Greenland, mild winter.

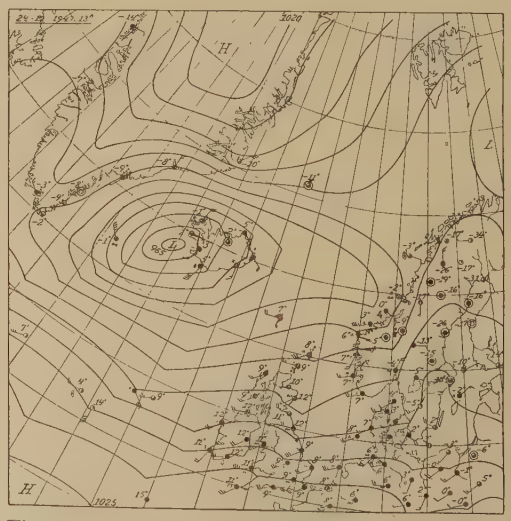

Figure 12. Europe, mild; Greenland, severe winter.

(Folia Geographica Danica, Tom. V. Copenhagen, 1949.)

2.

The Increase in the Sea Temperature in Northern Waters during recent Years.

By

Jens Smed

The increase in the atmospheric circulation and the rise of air temperature that has taken place over great regions of the world during recent years have been accompanied by an increase in the water temperature over vast areas of the sea.

The increase in the sea temperature—like that of air temperature—is especially pronounced in the Arctic. On the "Fram" expedition in the years 1893—1896 Nansen found in the Arctic Ocean a surface layer 200—250 m. thick at temperatures from — 1·0° to — 1·9°, and below this a layer of Atlantic origin with a temperature of + 1·2°. This result was confirmed when in 1901 a Russian icebreaker between Franz Josephs Land and Novaya Zemlya found that zero temperature was reached at about 200 m. and that below this layer the temperature rose to + 1·1°.

During the years 1927—1935 a series of Russian expeditions investigated the same areas (the waters between Franz Josephs Land, Novaya Zemlya and Severnaya Zemlya (Northern Land)), and now found that the cold surface layer was only 70—125 m. thick and that below this layer temperatures from 0·6° to 2·6° occurred. Schokalsky (1936) has found that the temperature rise in the Arctic Sea commenced in 1921.

In the Atlantic water north of Svalbard relatively high temperatures and salinities were found by Norwegian expeditions in the twenties and thirties. Mosby (1938) states: "from 1910 to 1912 a decrease in temperature and salinity has obviously taken place, from 1912 to 1922, 1923 and 1931 we have on the whole an increase".

From the North Atlantic north of 50° Lat. many observations of surface temperatures, collected and published by the Danish Meteorological Institute, are available. At the Hydrographical Department of the Council we have worked up the data by computing anomalies for each month of the whole period 1876—1947. As standard values we have used the grand monthly means over the period 1876—1915, published by Ryder (1917). The monthly anomalies found in this way were then averaged over the areas shown in Fig. 1. For some of the areas the resulting mean

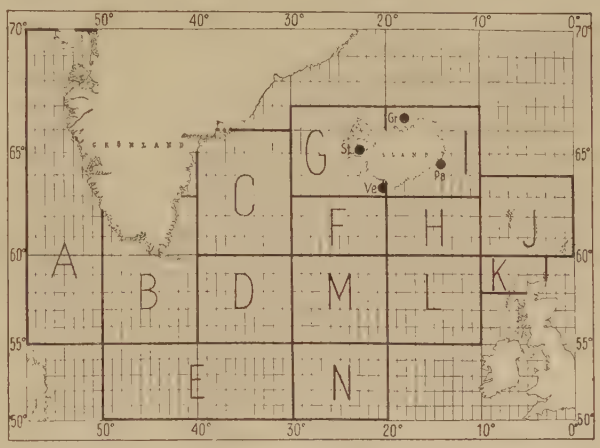

Figure 1. Location of areas and stations in the northern Atlantic.

anomalies have already been published (Smed 1947, 1948, 1949).

For the areas A and B near Greenland Fig. 2 gives a graphical representation of the results. The winter months have been omitted as the material from these months is very scarce in Greenland waters. It is obvious that positive anomalies have greatly predominated since the first half of the twenties. This applies to all months treated in Fig. 2.

It might here be added that the temperature increase in Greenland waters is not limited to the surface; Ad. S. Jensen (1939) records a series of

Table 1. Mean Anomalies of Surface Temperature at various Areas and Stations in the Northern North Atlantic.

(See Fig. 1.)

Period	1876 —80	1881 —85	1886 —90	1891 —95	1896 —1900	1901 —05	1906 —10	1911 —15	1916 —20	1921 —25	1926 —30	1931 —35	1936 —39	1940 —42	1945 —47
Locality A	0·5	0·0	0·2	0·0	0·0	0·0	—0·3	—0·1	—0·2	0·3	1·1	0·9	0·3	—	0·5
B	0·6	—0·1	0·1	0·2	—0·1	—0·1	—0·4	—0·3	—0·3	0·0	0·8	0·6	0·2	—	0·2
C	0·4	0·1	0·0	0·9	0·0	0·0	—0·2	0·0	—0·2	—0·3	0·9	0·8	0·7	—	0·8
D	0·4	—0·3	0·3	0·6	0·1	—0·2	—0·4	—0·3	—0·1	—0·3	0·4	0·5	0·4	—	0·3
E	0·3	—0·6	0·9	0·5	0·4	—0·3	0·0	—0·5	—0·3	—0·2	—0·1	0·3	0·1	—	—0·4
F	0·4	—0·2	0·0	0·3	0·0	—0·2	—0·3	—0·3	—0·4	—0·6	0·2	0·3	0·3	—	0·6
G	0·6	0·1	—0·4	0·2	0·0	—0·1	—0·2	—0·2	—0·3	—0·6	0·2	0·4	0·5	—	1.0
H	0·4	—0·1	—0·1	0·1	0·0	0·0	—0·2	—0·2	—0·4	—0·4	0·1	0·3	0·4	—	1·0
I	0·3	—0·1	—0·5	0·1	0·0	0·1	—0·1	0·0	0·2	—0·2	0·6	0·8	1·0	—	1·6
J	0·3	0·2	—0·3	—0·1	—0·1	0·0	—0·2	—0·1	—0·3	—0·2	0·1	0·3	0·6	—	1·0
K	0·0	0·1	—0·1	0·0	0·2	—0·1	—0·3	—0·1	—0·2	—0·1	0·1	0·3	0·4	—	1·0
L	0·2	—0·1	0·1	0·1	0·3	—0·1	—0·3	—0·2	—0·2	—0·3	0·0	0·3	0·4	—	1·1
M	0·2	—0·4	0·4	0·4	0·3	—0·1	—0·2	—0·3	—0·3	—0·4	0·0	0·4	0·2	—	0·6
N	(0·5)	—0·5	0·5	0·6	0·4	—0·2	0·0	—0·3	—0·1	—0·4	—0·2	0·1	—0·1	—	—0·1
Ve	0·4	—0·3	—0·5	0·0	0·0	0·0	0·2	0·3	0·3	0·5	1·1	1·1	1·2	1·4	
St	0·6	0·1	0·1	0·0	—0·5	—0·3	0·0	0·0	0·3	0·0	0·7	0·6	0·3	0·4	
Gr	1·4	—0·1	—0·3	—0·2	0·1	—0·5	—0·3	0·0	0·2	0·7	1·4	1·6	1·8	1·5	
Pa	0·3	—0·2	—0·6	—0·4	0·4	0·3	—0·1	0·3	—0·1	0·7	1·6	1·4	1·7	1·6	

examples showing a very conspicuous temperature increase at all depths.

From the monthly anomalies, yearly, and later on five-yearly, mean values of the anomalies were computed for the various areas. The five-yearly mean values of the anomalies are recorded in Table 1. Because of the gap in the material caused by the second world war, periods comprising less than five years have been chosen for the later part of the data.

A conspicuous feature of the table is the predominance of positive anomalies after 1925. In fact, after this year negative figures occur in the columns of Table 2 for the areas E and N only, i. e., for the two areas situated south of 55° Lat. In the western areas (A and B) the positive anomaly has obviously already reached a maximum value during the period 1926—30. In the middle areas (C and D) the values are fairly constant from that period, while for the eastern areas (F, G, H, I, J, K, L, M) the positive anomaly has been increasing constantly from the middle of the twenties. A comparison of the positive anomalies found for the various areas shows in most cases increased values to the north.

The period of positive anomalies was preceded by a period of negative anomalies, lasting from the beginning of the century to the first half of the twenties.

In Table 1 are also included anomalies of surface temperature at 4 stations situated near the coasts of Iceland (see Fig. 1). At these stations the increase in temperature is evidently more pronounced and has apparently set in earlier than in the areas described above. It should be remembered, however, that the temperature conditions at these stations are influenced by the proximity of the land.

From a number of stations along the Norwegian coast also long series of sea-surface temperatures exist[1]). Hesselberg (1940), by computing consecutive average values for thirty years, viz., for the periods 1870—99, 1871—1900 .... 1909—38, arrives at the following conclusions:—

"In northern Norway the mean annual sea-temperature falls until the period (1888—1917), while the fall continues until (1897—1926) in southern Norway. Then a rise commences, amounting from 0°·7 to 1°·0 C. in the north and to 0°·2 to 0°·4 in the south of the country. This rise still continues."

In view of the importance to the fishery of the hydrographic conditions in the North Sea it was of interest to investigate whether an increase in temperature had also occurred in recent years in this area. This investigation was carried out for the five areas shown in Fig. 3 on the basis of data contained in the Council's Hydrographical Card-Index. Anomalies for each month in the period 1902—1939 were computed, using as standard values the monthly means over the period July 1905—June 1914 published in the *Bulletin Hydrographique* (1922). These results have already been published in the *Annales Biologiques* (Smed 1947 a, 1949 a) where details concerning the computation are given. Yearly and five-yearly mean values of the anomalies have now also been computed. Five-yearly means of the anomalies are recorded in Table 2; but the first and the last periods comprise only 4 years.

Evidently a temperature increase began at about the middle of the twenties. High positive anomalies in the thirties are outstanding.

The high surface temperatures in the thirties are also evident in Fig. 4, where the solid lines show

[1]) *Note added in proof:*—A detailed treatment of these data has now been published by E. Frogner (Means and Extremes of Sea Temperature by the Norwegian Coast.—Geofysiske Publikasjoner, Vol. XV, No. 3. Oslo, 1948).

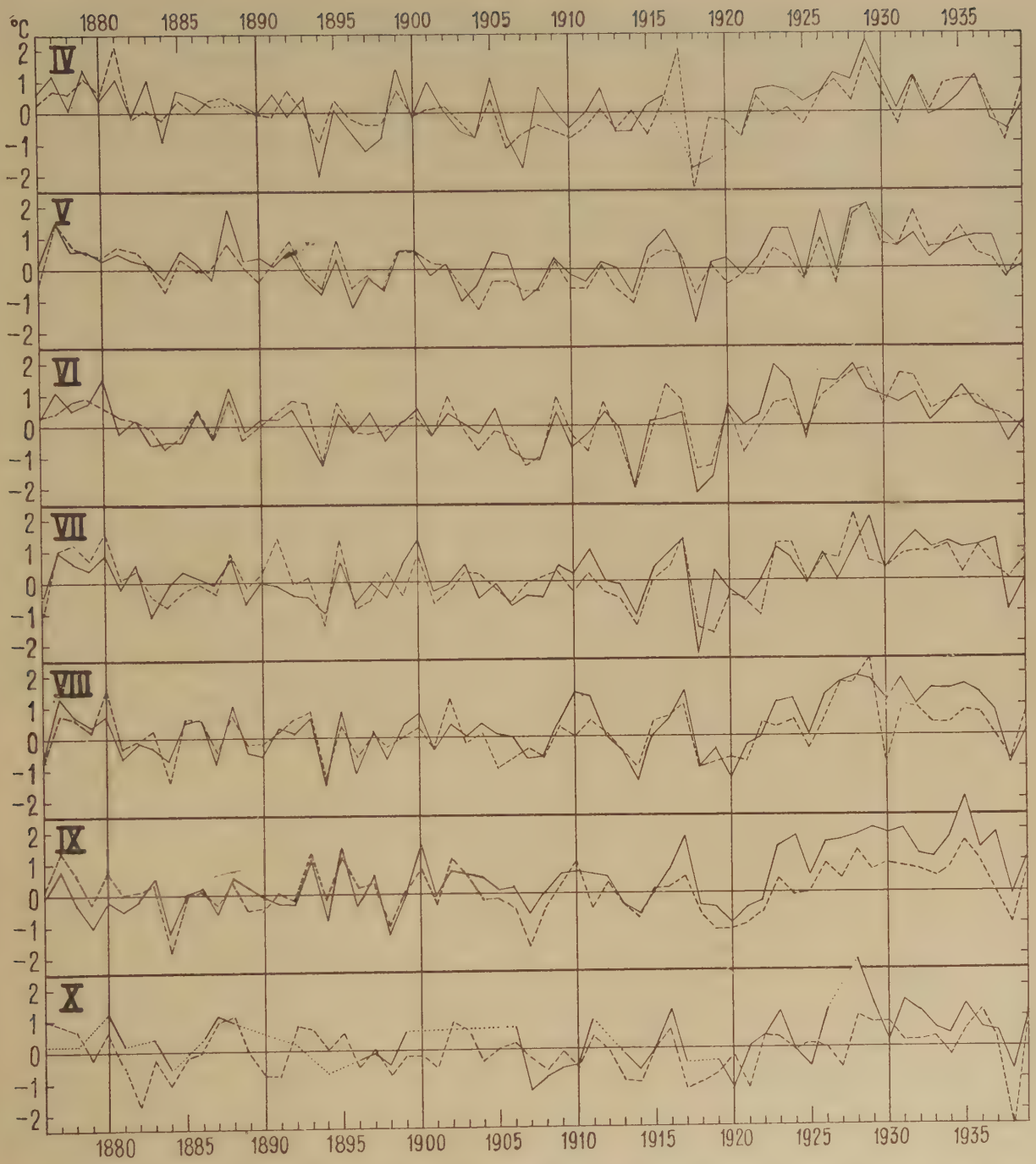

Figure 2. Monthly anomalies of the surface temperature in the areas A and B (see Fig. 1) during the years 1876 —1939. Solid lines: area A; dashed lines: area B.

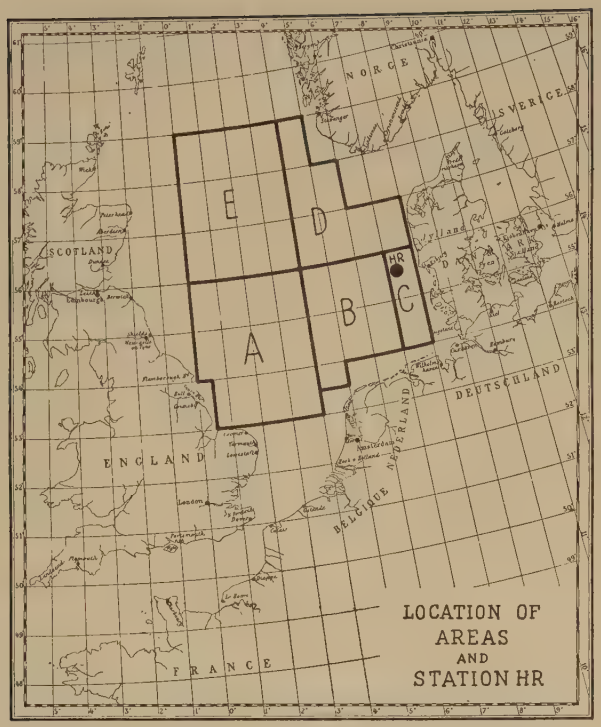

Figure 3. Location of areas and station HR in the North Sea.

monthly means of the surface temperature at Horns Rev Lightvessel (HR in Fig. 3). In each part-figure the grand monthly mean of the surface temperature for the period 1881—1930 is represented by a horizontal line through the figure.

Table 2. Mean Anomalies of Surface Temperature in Areas of the North Sea.

(See Fig. 3.)

Locality.....	A	B	C	D	E
1902—1905.....	0·3	—0·1	—0·2	—0·5	—0·2
1906—1910.....	0·0	0·0	0·0	—0·1	—0·2
1911—1915.....	0·2	0·2	0·3	0·3	0·1
1916—1920.....	(—0·3)	(0·4)	(—0·4)	(—0·8)	(—0·2)
1921—1925.....	—0·1	—0·2	—0·4	—0·2	—0·2
1926—1930.....	—0·2	—0·2	0·1	0·1	0·0
1931—1935.....	0·2	0·5	0·5	0·5	0·5
1936—1939.....	0·2	0·4	0·8	0·5	0·6

A very conspicuous feature in this figure is the close correlation between sea surface temperature and air temperature (shown by the dashed lines)—a correlation arising from the direct exchange of heat between air and surface water.

The interaction of air and water is, however, not limited to this direct exchange of heat. It must be expected that the increase in surface temperature in the northern North Atlantic will cause a deepening of the barometric minima and thus an intensification of the atmospheric circulation. This again may have intensified the North Atlantic current and its branches which may be the cause of the high sub-surface temperatures and salinities found in the Arctic Sea in recent years.

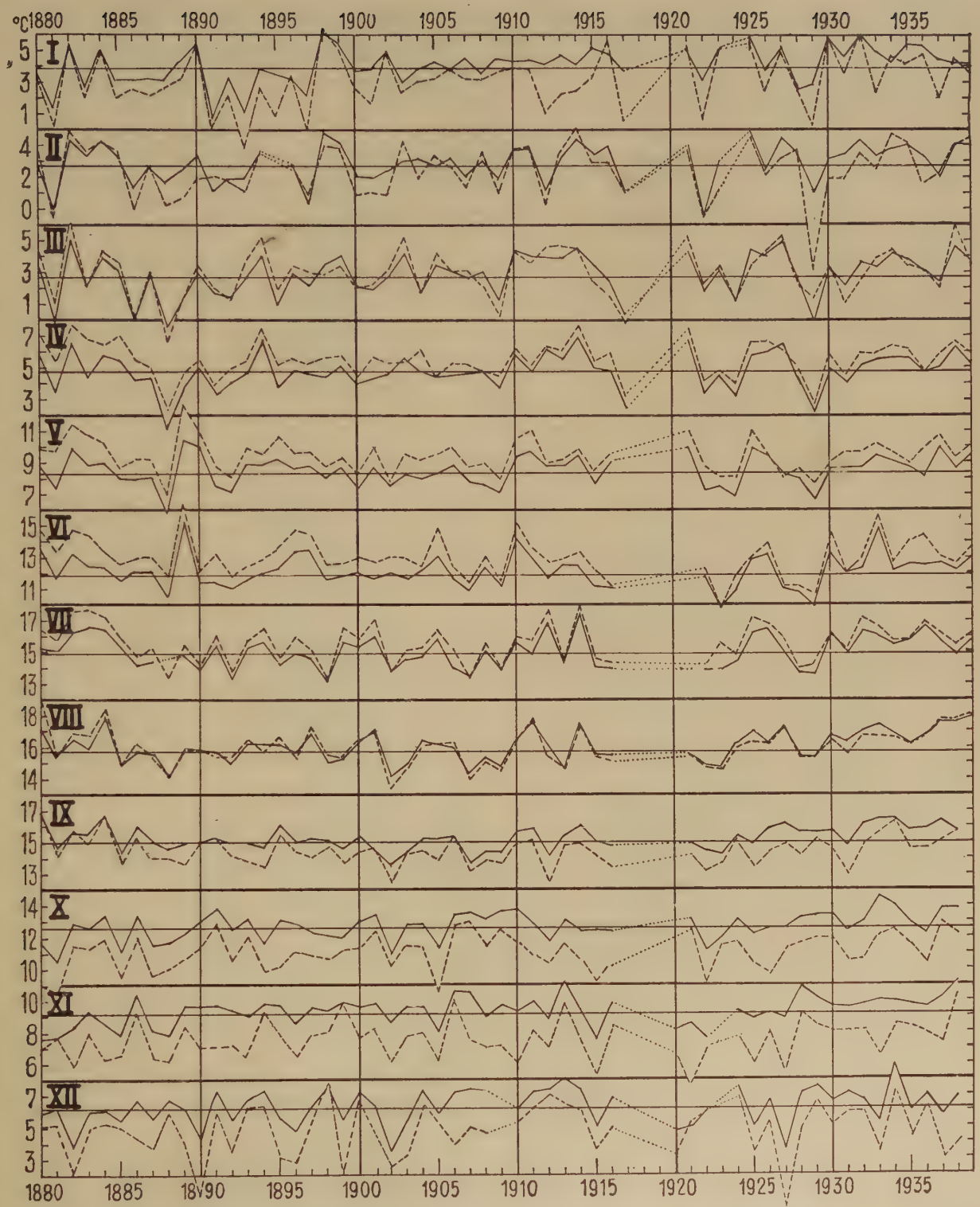

Figure 4. Monthly means of the surface temperature (solid lines) and of the air temperature (dashed lines) at Horns Rev Lightvessel (HR, Fig. 3) during the years 1880—1939.

Chart of Greenland.

1.

On Changes in the Marine Fauna of the North-Western Atlantic Area, with special reference to Greenland.

By

Å. Vedel Tåning

During the last 20 years it has become increasingly clear that the rise in sea temperatures has had a much stronger influence on the animal life in the boreal and arctic regions of the North Atlantic than any of the known previous mild climatic periods during the last 150 years. A more systematic investigation of the matter was therefore desirable, and at the Stockholm Meeting in 1946 I proposed in the North-Western Area Committee that much more attention should be directed to the significance of this climatic change for the fishery (see Rapp. et Proc.-Verb. Vol. No. 117, 1947, I, p. 29). At the meeting in 1947 a recommendation was adopted in this committee after the Vice-Chairman and I had discussed the possibilities for a joint study of this important problem under the auspices of the International Council (see Rapp. et Proc.-Verb. Vol. No. 121, 1948, I, p. 32). The recommendation resulted in this meeting and through the "Enquiry" a collection of much valuable material was obtained.

It is however not possible to put before this meeting the many observations from the hundred contributors to the enquiry. We have therefore decided to emphasize the main trends in the influence of the climatic changes by giving short reviews from the three main more or less arctic areas in the North Atlantic where the influences have been strongest and of outstanding importance to the fisheries, namely the north-western section (Greenland and the surrounding seas), the central section (the Iceland area) and the north-eastern section (Norway, Svalbard, Barents Sea). Moreover information on the hydrography and on terrestrial animals will be given; the first as the foundation for changes in marine animal communities, the last as a valuable supplement to the marine observations.

When we began research work after the first world war, in 1924, in the north-western area, in Iceland and Greenland waters, it was obvious that the environment for marine life had altered compared with the knowledge of these waters gained at the beginning of the century by the research work of the late Johs. Schmidt and Professor Ad. Jensen. At Iceland in that year I found cod spawning along the north and east coasts, where Schmidt in 1903—05 never noticed cod eggs; and at West Greenland large cod were met with in much greater quantities than Professor Ad. Jensen had seen in 1908—09, and moreover the sea teemed with small cod. The fry of the redfish was obtained in 1924 in contrast to Jensen's experiences at the beginning of the century. I will mention here that in the same year (1924) the first note on a conspicuous change in hydrographical conditions in the western section was published (in "Science"), namely an observation by the International Ice Patrol of a rise in temperature in the New Foundland area. The note predicted that a similar change would soon be observed in north-eastern European waters.

During all cruises in the north-western area since 1924 it was obvious to me that the general rise in temperature, masked sometimes by greater or smaller fluctuations, was followed by great differences in the distribution, density etc. of the various fishes compared with the observations at the beginning of the century. The changes in Greenland waters were, as is well known, of great economic importance for the fisheries, and Prof. Ad. Jensen studied the conditions in this area from 1925. During the cruise with the "Dana" to West Greenland he got a strong impression of the alterations which had occurred since his cruises on the "Tjalfe" in 1908—09; the results were mentioned in some papers in 1930, 1931 and 1935 and published in detail in his paper of 1939,

which is now a classic work on the problem. In the Iceland area during the same period, the late BJARNI SÆMUNDSSON studied the conditions off Iceland, and his paper, written in 1932, was issued in 1934.

As is now well known the rise in temperature has been observed in several coastal waters, especially of the arctic seas; but the surface temperatures of the open North Atlantic also show a rise, the origin of which has been traced to the Gulf Stream. The rise is however also found in deeper waterlayers: north of Iceland to a dept of about 400 metres ("Dana"), off Spitsbergen to a similar depth (SVERDRUP), and in 1947—48 we found a rise of about 1° in the open sea south of Iceland to a depth of about 700—800 metres compared with observations from 1903—05. From this area we get the warm water which flows to Greenland.

Unfortunately very few series of hydrographic observations are available from most areas for the first 20 years of this century. I have therefore endeavoured for several years to procure a basis for comparison in the future by working fixed sections in various parts of the north-western area. Several of these sections were recommended at the Council Meeting in 1934 and have been carried out many times; most of them are of immediate importance for the practical fishery investigations on the fishing banks, but we have also gradually recognised the value to the fishery investigations of sections in the open sea and have accordingly extended the work as far as time has permitted. I now consider this work to be of great importance for future studies in the trend of climatic changes in the sea. Biological and hydrographical work has of course been co-ordinated during this attempt to carry out continuous observations of the conditions in the open sea.

All the sufficiently extensive observations in the north-western area from the cold period at the beginning of this century show a certain change compared with present-day observations, and I suppose that if we had sufficient material most animals would show changes in distribution, density, propagation etc. For the north-western area we have two important contributions to the study of biological changes in recent times in the papers by AD. JENSEN and BJARNI SÆMUNDSSON. My task here is an easy one because Professor JENSEN's paper, supplemented by notes by Dr. PAUL HANSEN, unfolds the important features very clearly. As the paper by Prof. JENSEN is very well known I will confine myself to a short review of the cod question, supplementing this with a few observations on other fish of commercial value, but especially emphasizing the principal lines of the biological changes among the fish and a few other inhabitants of the northern seas.

The rise in temperature has been emphasized as the prime cause of the extension of various animals beyond their boundaries known before the present warmer period. And I suppose that this is correct; the rise makes an advance possible, but I think that the increase in density of the various animals depends also on other factors as light, phosphate, nitrate etc., in short the proper environment for growth, propagation etc. But it must be admitted that we know very little about the different links in the chain of factors involved.

For the western section the economic importance of the rise in the sea temperature is enormous. This is especially emphasized by the well-known increased yield of the **cod fishery in Greenland waters,** not only for the Greenlanders but for the fishermen of several countries. The yield of the Greenland cod fishery of West Greenland in the period 1910—1922 was not over 500 tons a year; in 1925 1,000 tons was reached, then there was a great increase up to 8,000 tons in 1930, followed by fluctuations, but in 1946 13,000 tons was passed; for 1947 the catch was 14,900 tons. The catch by Faroe fishermen and others has also on the whole increased and Danish fishermen have this year joined the fishing fleet going to Greenland. All this shows the increase in density; but of no less interest is the movement of the fishery from the southern part of West Greenland to the north during the last 20 years.

In the twenties the majority of the fishery was in the area between 60° and about 67°, being heaviest south of 65°; now the fishery occurs about 300 nautical miles farther north, with the heaviest fishing north of 65° (at any rate for the Greenland coastal fishery). When I carried out some cod investigations in these waters 24 years ago the cod was a rare fish in the Disko Bay area, many Greenlanders there had never seen a common cod; but in 1946 this was changed to such an extent that 30% of the total Greenland catch was secured in the districts surrounding this area. Professor JENSEN has described this development in a fascinating manner. It has been proved that this cod stock is an off-shoot of the Icelandic stock of cod, though retaining a certain interchange with this stock. However the Greenland stock now seems to have reached a certain stage of independence from the Iceland stock because increasing spawning now takes place in Greenland waters. All this has been described by Dr. PAUL HANSEN (Rapp. et Proc.-Verb. Vol. No. 123).

I will later mention that a similar increase has also occurred in other fish communities in these waters.

Now it is of great importance if similar warm periods have occurred in these waters during previous centuries. Professor JENSEN has pointed out that we have a few observations from this area which show that warm periods actually have occurred, but evidently not on such a large scale as the present. There was a period about 1820, when cod was abundant between Julianehåb and Disko Bay, and a second period in the forties of a similar scale, English fishing vessels taking part in this fishery. In Spitsbergen waters we had a "cod period" in the years about 1870—1880, but this period seems of minor import-

ance in Greenland waters, though information is scarce. However, the **halibut** fishing was good off Holsteinsborg in the years 1866—1881, though cod was scarce in 1879, only one cod to 15 halibut being taken by American fishermen on the long lines. The fact that halibut was plentiful shows, however, that a warm period occurred during these years. Later, during the long period prior to about 1920 nothing is known of the cod in these waters. Very few Greenlanders have had any interest in this fish during last century, sealing being the usual activity of the Greenland hunter. The Danish people up there have not left many records in the literature on fish or fishing. It is, however, clear that the periods mentioned have been observed over wide areas of the North Atlantic and the arctic seas. But as far as we can see the periods have been shorter and not so pronounced as the present—we have to discriminate between short periodic and long periodic fluctuations.

A closer study of faunistic material in various museums will probably give us some more information as to the preceding periods.

When we now turn to some other fishes of economic importance in these waters, we find a similar increase in density and dispersion to the north; and the same is the case with several fishes and other marine animals of slight or no importance.

It is convenient to group the many scattered records under a few headings to get a clear view of what has happened to the marine fauna, especially the fishes, in the north-western area during this century. The arctic and boreal animal communities meet here, and we will not for this purpose divide these two groups, which are on the whole clearly defined, into sub-groups (high-arctic, sub-arctic, high-boreal etc.).

A. Boreal forms:

1) **New immigrants** to the area: Tusk (*Brosmius brosme*) north to Umanak; Ling (*Molva vulgaris*) Frederikshåb; *Gadus poutassou* Julianehåb; Witch (*Pleuronectes cynoglossus*) from Lille Hellefiske Banke and Lichtenau Fjord.—The jelly-fish *Halopsis ocellata*.

The immigration of several of these animals has as far as we know occurred from the Iceland area via the Irminger current, none have come from the American area (the direction of the current prevents this to a high degree).

2) **Extension of distribution** to areas formerly covered with colder water: Cod (*Gadus callarias*); Halibut (*Hippoglossus*), north to Upernavik; Spotted catfish (*Anarhichas minor*) to northern part of Melville Bay; Herring (*Clupea harengus*) north to Upernavik district (Prøven). — Mussel (*Mytilus edulis*) north to Thule. *Asterias* according to Paul Hansen north to Disko Bay in 1948.

3) **Increased density:** several of the above-mentioned species Cod, Halibut, Spotted catfish, Herring, and moreover Coalfish (*Gadus virens*), Haddock (*Gadus aeglefinus*), Salmon (*Salmo salar*), Picked dogfish (*Squalus acanthias*), Dealfish (*Trachypterus*). — Common starfish (*Asterias rubens*). The Blackfish or Caaing whale (*Globiceps melas*) and other southern whales.

The increases in a few of the important food fishes have as mentioned been enormous.

4) **Reproduction** observed in areas previously outside the normal area of propagation: Herring (*Clupea*), Coalfish (*Gadus virens*), Redfish (*Sebastes marinus*) and probably some of the rare immigrants.

5) In recent years some animals have stayed during the winter in more northerly quarters than formerly; this behaviour has been observed in the sea (several species of fish) and on land (birds).

B. Arctic (sub-arctic) forms:

1) **The southward migration** of true arctic forms has occurred later in autumn than previously: e. g., White whale (*Delphinapterus leucas*), Narwhal (*Monodon monoceros*).

2) **A decrease in density** on the warmer parts of the coasts and an **increase** on the colder parts:

Capelan (*Mallotus villosus*), which moreover has extended its distribution north to Thule on the west coast and to Scoresby Sound on the east coast; Ogac (*Gadus ogac*); Greenland Halibut (*Reinhardtius hippoglossoides*); Greenland Shark (*Laemargus microcephalus*).

Of paramount importance to the fishing industry, to the Greenlanders, the Faroese and several other countries, are the questions: How long will this warm period continue? Have we passed the peak? From Greenland waters we have as far as I know no certain evidence that we are on the decline; there have been some variations, but a general return movement over several years has not yet been observed, probably the opposite is true. If we had a greater number of observations from the past on temperatures in the sea etc. it would probably be possible to see the trend for the coming years.

However our attention is now directed to the importance of these studies, and well planned series of observations, physical and biological, in all North Atlantic seas and in the open ocean, will without doubt in due time show when the peak has been passed.

2.

Boreo-tended Changes in the Marine Vertebrate Fauna of Iceland during the last 25 years.

By

Árni Friðriksson

Introduction.

There is a good deal of evidence indicating that the higher temperatures in the air and in the seas round Iceland in recent years have influenced the fauna as well as the flora of this country, which have tended to become more southern than previously. As regards the flora, I just want to note that some formations of the vegetation on the north-eastern part of the country have altered distinctly from being subtundra-like to becoming of a more boreal status during the last 25 years or so. The faunistic changes which have taken place can only be explained through the influence of higher temperatures, and I am not aware of any evidence which points in the opposite direction. In 1932, the Icelandic scientist Sæmundsson published a paper on this matter: "Probable Influence of Changes in Temperature on the Marine Fauna of Iceland", and since that time several contributions have been published in Icelandic periodicals. I will now confine myself to giving a brief description of the changes which have taken place in the marine fish and mammal fauna in Icelandic waters since about 1925.

I. Fish.

145 species of marine fish are now known from Iceland, most of which are Atlantic, the remainder belonging to the Polar Sea region. Not less than 37 species of those 145, or more than 25 %, give evidence of changes indicating higher temperatures. They can conveniently be divided into 4 groups, as follows:

1) New visitors from the Atlantic, not previously recorded.

2) Previously recorded visitors seen more frequently during later years.

3) Species extending their distribution to the colder parts of the coast, and

4) More uncertain species.

Of group 1, nine Atlantic species have been recorded new to Iceland in the period dealt with here. These are:

(a) The **swordfish,** one specimen taken off the east coast in 1936.

(b) The **spotted dragon** (*Callionymus maculatus*), three specimens caught off the south and south-west coasts in 1935—1936.

(c) The **pollack,** six specimens taken in the years 1938—48.

(d) The **twaite shad** (*Clupea finta*), 31 fish caught in two hauls in 1933 and 1939.

(e) The **ray** *Raja nidarosiensis*, five specimens recorded in 1924.

(f) Not less than four new species of scopelins have been recorded.

Of group 2, 14 formerly recorded Atlantic visitors have appeared more frequently during recent years than previously. They are:

(a) The **mackerel,** which has often been recorded sporadically. This fish was unusually common during the summer 1944, at least off the north-west and north coasts where many were caught in purse-seines in the Isafjord-deep and still more off the north coast, where 450 were landed one day, 1164 another day, and shoals were observed in the surface of the sea.

(b) The **tunny.** Before 1929 only six records had been made, but in 1929—1932 it became more numerous, it appeared in pairs or even in small shoals, some 10 to 20 at once. In 1944 the tunny was more numerous than ever off the south and west coasts, where five fishes were caught with hand lines.

(c) The **horse-mackerel** (*Caranx trachurus*). Until the year 1937 only one specimen had been recorded, but in this year a small shoal appeared in Hafnarfjord, on the south-west coast. In the summer of 1941 this fish appeared in extremely great numbers almost everywhere, being one of the most common fish in Icelandic waters during this period. The length

of the specimens measured ranged from 12 to 16 cm. All the fish seemed to belong to the I-group.

(d) The **thick-backed gray mullet** (*Mugil chelo*) has been observed 10 times, 10 fishes in all, until 1928. Since that time 16 more have been recorded.

(e) The **gadoid fish** *Phycis blennoides*, which was previously only recorded once, in 1903, has appeared to be fairly common during the last 10—15 years.

(f) Only two specimens of the **bulbid** *Paralepis kröyeri* had been recorded until 1927, but in 1930 SÆMUNDSSON found a great number of this fish in coalfish stomachs off the east coast.

(g) One specimen only of another **bulbid** *Paralepis brevis* was found in Faxa Bay in 1900. In 1925 and 1939 two more specimens have been recorded, one of which was off the east coast.

(h) 14 specimens of the **conger-eel** have been recorded from Iceland since 1909, 10 of which were after 1925.

(i) Only one specimen of the **ray** *Raja lintea* had been recorded up to 1926, but several more have been found since that time, not only off the south, but also off the north-west and north coasts.

(j) 16 specimens of the **skipper** (*Scomberesox saurus*) had been recorded before 1927, all from the south and west coasts. Since then seven more have been found, one of which came from the north and another one from the east coast.

(k) The **basking shark** (*Selache maxima*), which is not an uncommon visitor to the south and west coasts, was recorded off the north coast in 1927 and the east coast in 1931.

l) Three specimens of the **Cornish blackfish** (*Centrolophus britannicus*) had been recorded off the south coast in 1906—1922 and one was taken off the north coast in 1946.

(m) *Scopelus elongatus*. Three specimens had been recorded from the south coast before 1925, but after 1930 four more have been added, one of which came from the north-west coast and one from the east coast.

(n) The **thornback ray** (*Raja clavata*). Four specimens are known from Iceland, two of which were obtained in 1937.

Of group 3, five species, which are more or less abundant in Icelandic waters, and none of which can be regarded as visitors from the Atlantic, have extended their distribution further north and east during recent years. One of these is the cod, which I will mention later, together with the herring, which seems to hold a separate position.

(a) The **turbot** was recorded four times in the south and south-west before 1925, later five more specimens have been found, three of which were off the east coast.

(b) The **witch** had always been limited to the south and south-west coasts, but since 1925, it has been recorded all around the island.

(c) The **great silver smelt** (*Argentina silus*) had not been found off the north coast until 1946.

(d) Since 1928 the **capelan** (*Mallotus villosus*), which was previously extremely numerous off the south coast has been much less frequent there, and in some years has been absent. At the same time it has appeared earlier in the year and in a far greater density than previously off the north coast.

(e) Finally, the **Greenland shark** has almost left the old fishing grounds and moved farther to the north.

Group 4. In the fourth group, which comprises nine species, we have to deal with fish which have probably been more frequent in recent years than earlier, although this may, in some cases, be regarded as doubtful.

(a) The **meagre** (*Sciaena aquila*) has been recorded once, in Reykjavik, 1923.

(b) The **oarfish** (*Regalecus glesne*) has been found three times before 1925 and once later, in 1933.

(c) Of the **dragonet** (*Callionymus lyra*) two specimens are known from Iceland, one of which was obtained in 1934.

(d) *Ceratias holbölli*, three specimens were found before 1925, one in 1936 and one in 1938.

(e) *Scopelus maderensis*, two specimens were found in 1885, one in 1932.

(f) The **sunfish,** seven fish were recorded during the last 100 years, three of which were after 1930.

(g) The **sturgeon,** four specimens were recorded during 190 years, one of which was in 1945.

(h) The **six-gilled shark** (*Notidanus griseus*), two specimens habe been recorded, one in 1920, the other in 1933.

(i) The **dogfish** *Pseudotriakis microdon*, three were taken in the period 1900—1915, one in 1943.

The cod.

As far as fisheries investigations go back, and in this century, until the twenties, the Icelandic cod-stock has been spawning off the south and south-west coasts in spring, and migrating into the cold water area in the west, north and east in search for food during the summer months. This behaviour has largely changed during the last 20 years or so, and the development can be divided into three stages.

1) Towards the end of the twenties a large-scale migration to Greenland used to take place after the spawning, followed by a failure in the summer catches off the north-west, north and east coasts. In these years the cod migrated back to Iceland in great numbers in order to spawn.

2) In the beginning of the thirties the spawning places were not so strictly limited to the south and south-west, as some spawning took place, at least in some of these years, practically all around the island.

3) After 1937 the density of cod on the spawning grounds was very low, as the cod obviously did not need to migrate all the way to the old grounds to find suitable spawning conditions. This resulted in a failure in the yield of spawning cod for a series of years. Since 1942 the development has shown these trends to be reversed as the fishing has gradually become better again.

The herring.

Before 1945 enormous masses of herrings visited the waters of the north coast of Iceland in July and August, more or less regularly every year. At the same time there was practically no fishing off other parts of the coast, or at other seasons, but with some insignificant exceptions. During the last four years the yield of the north coast fishery has grown smaller and smaller and this summer, which has seen the poorest ever remembered, it has only amounted to a small fraction of the normal yield, only $^1/_8$th or so of what could have been expected. In connexion with this it must be noticed, that the surface temperature of the sea off the north coast during the summer months has been higher than it used to be and the fishing grounds have on the whole moved further eastward. Hand in hand with this development two other, more local, previously small stocks of herring have expanded enormously and last winter gave rise to a new fishing season on the south-west coast. The number of young herring in Icelandic waters has also increased greatly, so that their density is now many times larger than before.

II. The Mammals.

We now come to 19 species of whales, 7 species of seals and, if we include the polar bear, a total of 27 species of marine mammals in Icelandic waters.

Two of the seals, the **common seal** and the **grey seal** are stationary all around Iceland all the year round and have not changed behaviour in recent years, as far as I know. The remaining five, the walrus included, are arctic animals, which have been much less frequent during our generation than often before.

The visits of the **polar bear,** which is a true follower of the ice, are dependent on the drift of the ice up to the coast and have consequently been more and more scanty. Only three visits have been recorded during this century, one of which was after 1926.

Of the 19 species of whales, 17 give, as far as I can see, no evidences on the matter, neither for nor against, the two left being the sperm whale and the Caaing whale.

The **sperm whale** was pretty often taken by the Norwegian whale-hunters in Iceland during the last years of the 19th and the first years of the 20th century, but only off the eastern part of the south coast. Since the Icelanders started whaling in 1936, some have been caught off the south-west and even off the north-west coast, a phenomenon that never happened in the former period.

As regards the **Caaing whale,** it has usually appeared as an infrequent visitor, being recorded only twice during the last quarter of the last century, twice during the first quarter of this one, but not less than 11 times in the period 1926—1945, that is to say, seven times more frequent now, than previously.

If we now try to summarize what has been said above, we come to the result, that, of 145 species of fish found round Iceland, 37 give evidence of changes, 9 being new, 14 or perhaps 23 more frequent, and 5 more northerly. Similar evidence is clearly shown by at least 2 species of whale.

We do not know much about previous warm periods, but we can almost take it for granted that we have had three during the last century. Thanks to a visit of the naturalist FRIEDERICH FABER we have good reason to suppose that there has been a relatively warm period about or after 1820 and there are many facts that indicate another period just before the middle of the century, among other things some information given by the Icelandic naturalist HALLGRIMSSON. Finally, we had a third period about 1870 when, for instance, the behaviour of the herring was quite different from that which it became later and more like the situation it seems to be approaching now.

3.

Fluctuations in two of the Most Important Stocks of Fish in Northern Waters, the Cod and the Herring.

By

Gunnar Rollefsen

When the herring and cod appear off the Norwegian coast, the visit is of but a short duration, and although the sea may seem inexhaustible for some years, the following year it may appear empty of fish. Man is never allowed to feel secure. This fact increases the tension in the mode of life, it calls for initiative, but it can also stifle the will and break the power to fight for a solution.

It is evident that the fisheries have influenced the history of Norway to a great extent, and we can trace their influence on settlements and living conditions thrcugh the centuries. Some of the features of the Norwegian peoples' character may even be explained by the demands of the fisheries and the irregular behaviour of the fish.

As the fisheries have been of great importance to the economic welfare of Norway as far back as we are able to look, it was an occurrence with far-reaching consequences when the fish failed to reach the coast. The many accounts of bad years when the "skrei" and herring fisheries failed are clear evidence of this. It was not too fatal when one bad year occurred in a series of many good ones, but it was the occurrence of many bad years in succession that hampered the economic and cultural development of the community. Whilst the fishing boats and nets rotted, the experience and knowledge gained were also buried.

For the last 25 years cod and herring have appeared in great quantities along the coast of Norway. In this way our generation has been lucky, but we don't have to go back more than 25 to 30 years to find the poor years of the cod fisheries, and 70 years ago practically no herring was found on the coast.

The causes of these fluctuations have without doubt been discussed with equally great interest through the ages, and there is no basic difference between the old belief in God's influence on the output of the fisheries and modern theories of cosmic rays and sun-spots. Both theories point to the fact that the causes of the fluctuations are outside the control of man. There is, however, one considerable difference. By means of scientific methods modern man has tried to get a knowledge of the nature of the variations. We ask if the fluctuations may be connected with other varying conditions, and if it may be possible to secure any advance information on the fluctuations.

The Fluctuations in the Cod Fisheries.

Considering the yield of the Lofoten fisheries during the last 80 to 90 years, some features are clearly evident. Firstly, great fluctuations may occur from year to year; secondly, the catch may be favourable for 3 to 5 years followed by a decreased output during the next few years; and thirdly, fluctuations of a longer duration seem to prevail. The fisheries in Lofoten from about 1870 to 1900 gave very good results. From 1900 to 1920 the output was very small, but from 1920 until today the return has again been very high. An analysis of these features shows that 1) the yearly fluctuations largely coincide with favourable and unfavourable meteorological and hydrographical conditions during the fishing season, 2) the fluctuations of 3 to 5 years duration can be correlated with fluctuations in the size of the year-classes, and 3) the fluctuations involving longer periods of about 25 years duration also seem to be caused by the size of the year-classes, but in such a way that for a number of successive years large year-classes do not seem to be born, while the year-classes are large in the years that follow.

The question of the causes of the fluctuating size of the different year-classes has not yet been satisfactorily answered, and for the time being we cannot point to any direct causality, but by comparing the fluctuations in the stock of cod with changes in other

conditions, we have got some data of considerable interest.

The prolific period from about 1870—1880 occurred when the fishermen in Lofoten used rowing boats and sails, and the catches were taken with very small numbers of nets and lines. *During the poor period from 1900 to 1920* the motor-boats first made their appearance in Lofoten, and it is reasonable to presume that this made the fishing more effective, but all the same the catches remained small for 20 years. *In the last prolific period* the fishing intensity on this cod population was immensely increased by other nations taking their share of the cod in arctic waters.

We are accordingly not able to demonstrate any relation between these variations of long duration and the intensity of the fishing.

On the other hand, however, there seems to be a connexion between the output of the Lofoten fisheries and the distribution of the cod in arctic waters. It is a striking fact that during the good fishing period in Lofoten in 1870 to 1880 the fishing on Spitsbergen was also very good, but in 1883 the fish suddenly disappeared from these northern waters, at least from the shallow water areas. During the following years, when the Lofoten fisheries were poor, we have no information of fishing of any importance from these northern parts. But at the same time as the Lofoten fisheries increased in the twenties the fishing again improved around Bear Island and Spitsbergen.

Very interesting are the observations made during later years. The fishing around Spitsbergen and Bear Island is once again showing a tendency to decrease. At the same time it has been noted that the banks in these regions are covered with cold water to a greater extent than before.

How the cod population as a whole reacts to changes in the hydrographical conditions is more or less an open question, but experience gained by the fishermen indicates that the mature cod seem to avoid low temperatures, even if the immature cod seem less susceptible.

Furthermore there are signs which seem to indicate that the density of the stock has a decided effect on the growth of the individual cod.

We may therefore consider the amount of food available as one of the factors deciding the size of the skrei population. As the hydrographical conditions directly or indirectly influence the living space available to the cod, by opening or closing large feeding areas, it must be considered possible that the cold water masses which during recent years have covered the usual fishing banks to an increasing degree, will reduce the food available to the cod and thereby also influence the qualitative and quantitative properties of the stock.

The Fluctuations in the Herring Fisheries.

It is a well known fact that the stock of Norwegian large- and spring-herring has shown great fluctuations during the course of time. However the historical and statistical data available are better with regard to the second of these big seasonal fisheries along our coast.

In the writings of Peder Claussøn Friis (A.D. 1614) we find a great deal of valuable information about the herring fisheries in olden times. The information gained from him has a special value because it refers to events taking place during his own lifetime, but it is worth while noting that he maintains that the herring fishery in Viken (the old name for Oslofjord) during the reign of king Håkon Håkonson (A.D. 1263) ceased by witchcraft because a copper-horse was lowered into the sea.

From his own time he tells about two herring fisheries, one took place between Stavanger and Bergen, the other one in Viken. He does not know at what time the fishing on the west coast started, but he mentions that it began to decrease in 1560 and ceased completely some years afterwards.

Another herring fishery, however, originated in Viken in 1556, a few years before the fisheries in western Norway ended. But the fishing in Viken seems to have already ceased in 1567.

By reading the old sagas we can also get a glimpse of the herring fisheries even farther back in history. Egil's saga mentions a herring fishery in the 9th century, probably taking place outside Møre. During the reign of Harald Gråfeld (A.D. 969) bad years occurred inland as well as on the coast, whilst the fishing under Håkon Adelstein (A.D. 961) was on a large scale. In the sagas of Olav den Hellige (A.D. 1031) and Harald Hårdråde (A.D. 1015—1066) mention is made of great herring fisheries along the coast of Skåne in Sweden, and during the time of king Sverre (A.D. 1202) extensive fishing for herring was done in southern Norway.

From other sources we know that in the 13th century very big herring fisheries took place at Skåne, and in the 16th century by the coast of Bohuslän (also in Sweden).

As far back as history reaches the herring fisheries seem to fluctuate, but not until we get to the 16th century do we get any knowledge of the consequences of the variations, and from that time we also obtain more definite information with regard to the years when the fishing started and ended.

As previously mentioned one herring fishery in west Norway ceased about 1560. Around 1600 it seems that another regular herring fishery win operation, but this fishery has in any case ended in 1650, and it appears that the herring did not return to the coast until about 1700.

In 1784 the fishing in west Norway had again finished. The herring did not reappear until about 1808, and the herring period which then started lasted until 1876. But as had happened so often before, the herring vanished from the coast, and they had been absent for 20 to 30 years when around the turn of the century they returned. A new period then began, the period in which we are today.

The duration of the herring periods in the western

parts of Norway has, as far as we can see, varied from about 50 to 80 years, while the intermediate lapses, when no herring were present, varied from 30 to 60 years.

In the publication *Norwegian Fisheries* Løberg states that the herringless period from 1650 to 1700 is the longest series of years in more recent times in which no spring-herring fisheries are referred to. He mentions that this period perhaps comprises the 60 years which, tradition says, the herring is away from the coast.

The herring fisheries in Viken and near the coasts of Bohuslän and Skåne in Sweden, have been intermittent in the same manner as those in western Norway, but we can follow the herring periods near Bohuslän farther back than we can the Norwegian ones.

The strange thing is, however, that the periods of the fishery near Bohuslän and in west Norway have shown a clearly alternating character.

There is little reason to believe that the alternating nature of the periods is due to a change in the approach of the same stock of herring. The stock of herring appearing off the coast of west Norway does not seem to be the same as the one seeking the coast of Bohuslän. The large- and spring-herring in west Norway has its home in the Norwegian Sea and in northern waters, while on the other hand the Bohuslän herring belongs to the North Sea.

When therefore the herring has disappeared from the Norwegian coast for many years, but at the same time is present on the Swedish coast, this may imply that the Norwegian stock of herring has been reduced on account of special conditions in nature, while on the other hand the North Sea herring has had more favourable living conditions. This possibility is emphasized because there seems to be evidence showing that the Norwegian stock of herring round about 1900 was small. In his paper "Mortality in the Tribe of Norwegian Herring" (Rapp. et Proc.-Verb. LXV, 1930) Einar Lea points out that the mature stock of herring in the year 1909—10 increased enormously due to the rich year-class of 1904, which at this time appeared in the spawning shoals. According to Lea's calculations our stock of spawning herring in 1910 was 9·5 times greater than the spawning shoals of 1909. Lea also mentions that the stock of herring since 1910 has never been as small as it was during the 3 years preceding 1910. Even though, owing to lack of observations, we cannot state anything definite about the comparative size of the stock before 1907, the information at hand should form a sufficient basis for a working hypothesis from which we may seek an explanation of some of the features causing the fluctuations in the large- and spring-herring fisheries.

If the spawning shoals of herring, owing to conditions in nature, do not seek the usual spawning grounds, but have to spawn in places less favourable, this may involve the possibility of a greater part of the eggs and larvae perishing, in due time reducing the grown stock. As long as the unfavourable conditions prevail, the stock will remain small. If the herring, because of changes in the factors determining its migrations, again finds its way to the favourable spawning grounds, a greater number of fry will develop and grow, which in due time should increase the spawning stock.

4.

On Changes in the Distribution of Terrestrial Animals in Relation to Climatic Changes.

By

Poul Jespersen

In the following remarks I will make some observations on the changes in occurrence and distribution of terrestrial animals which may be correlated with climatic changes. The material available is principally from the literature; based on papers sent in to the International Council.

By far the largest number of observations on terrestrial animals has been made on birds. Therefore in the following short summary we deal especially with this group.

Owing to an increasing activity in ornithological observations during the last decades of the 19th century and up to the present time, it is quite obvious that the number of species recorded has been increasing in different countries; this fact naturally must be taken into consideration. Nevertheless it seems evident that the bird-life in northern Europe and America has been extensively influenced by climatic changes in more recent years. A striking example is that several species of birds have immigrated into different countries during the recent mild period and have been found breeding there. Most of these birds have appeared as visitors from more southern latitudes. According to Salomonsen (1948) the following species of more southern origin have immigrated as breeding birds to countries bordering Arctic and North Atlantic waters:

Greenland.....	5	new	species
Iceland	6	-	—
Faroe Islands ...	9	-	—
Denmark ..about	25	-	—

These breeding records must no doubt be due to the recent amelioration of the climate, moreover a number of southern species, boreal and even subtropical, have appeared as rare visitors in the various countries. Below is given a short survey of the avifaunal changes in the different areas mentioned, mainly based on the paper of Salomonsen (*l. c.*).

Greenland.

In the recent mild period a few southern species—5 altogether—have for the first time been found breeding in West Greenland, and this is no doubt primarily due to climatic changes. Among these birds I would especially mention a duck, the Pintail (*Anas acuta*), 10 pairs of which are said to have been breeding in a single locality in West Greenland this year; this species is not known to have bred in Greenland before.

It may further be mentioned that the White-fronted Goose (*Anser albifrons*), a southern species, has in recent years increased considerably in numbers in the northernmost parts of its breeding area. In West Greenland it has also been observed that several species over-winter in greater number than in former times, e. g., Mallard (*Anas platyrhynchos*), Long-tailed Duck (*Clangula hyemalis*) and others, and that some species stay in their breeding territory before moving to the south for a longer time than recorded in previous periods. Moreover a number of species, hitherto never observed in Greenland, have been recorded as rare and irregular visitors in recent years, especially since 1920. The majority of these new species are American birds, many have come from Iceland and a few from the European mainland. Since 1920 about 23 species new to western Greenland have been recorded, besides many species new to East Greenland. The great bulk of these species are southern ones.

In contrast, some high-arctic species in West Greenland have been observed most frequently during the cooler periods in the 19th century and have all decreased in number in recent years. This is the case for at least 5 different species.

Iceland.

A small number of southern species—6 altogether—have immigrated to the southern parts of Iceland as

breeding birds during this century, i. e., 3 species of Gulls (*Larus fuscus, L. argentatus* and *L. ridibundus*), the Swallow (*Hirundo rustica*), the Short-eared Owl (*Asio flammeus*) and perhaps the Starling (*Sturnus vulgaris*). They are now met with regularly or more exceptionally.

Further a number of southern birds, which have always been irregular visitors to Iceland have increased in number in this century and since about 1870, during which time the winter temperatures have steadily increased, many species have become regular winter visitors.

It must further be pointed out that a great number of new species in recent years have appeared as rare visitors to Iceland, coming from America as well as from Europe. Since 1935 no less than 18 different species have been recorded as new birds in Iceland.

Faroes.

In the Faroe Islands only 3 species have immigrated as breeding birds as a result of the climatic change, namely 2 species of Gulls (*Larus canus* and *L. ridibundus*) and a Storm Petrel (*Oceanodroma leucorrhoa*), but in recent years (after 1935) 6 southern species have immigrated to the Faroes. Altogether 9 different species have thus appeared as new breeding birds in the Faroes during this century and the last decades of the 19th century. Some of them, e. g., the House-Sparrow (*Passer domesticus*), the Lapwing (*Vanellus vanellus*) and Common Redshank (*Tringa totanus*) are now fairly widespread on the islands. From recent publications on the bird-life in the Faroes it also appears that some passage- and winter-visitors have increased in numbers and now spend a longer time on the islands than in previous periods.

The bird-life in the Faroes is so well-known and the reports on occurrences of rare visitors in recent times so numerous that it is impossible to go into details. It may only be said that in the recent mild period the number of new species on the islands has steadily increased and among them there are many markedly southern species.

Denmark.

Considerable changes have taken place in the avifauna in this country during the last 50 to 60 years. Up till 1930 16 new species have immigrated as breeding birds from the south, having come from the northern parts of Germany; this may be due primarily to the amelioration of the climate. The majority of species immigrated to Denmark before 1930, the Chiffchaff (*Phylloscopus collybita*), the Black Redstart (*Phoenicurus ochrurus gibraltariensis*), Great Reed-Warbler (*Acrocephalus arundinaceus*), Black-necked Grebe (*Podiceps nigricollis*), Tufted Duck (*Aythya fuligula*), and Montagu's Harrier (*Circus pygargus*) have continued to increase in numbers and have spread over many parts of the country. Since 1930, however, 9 further species have immigrated. Some of the species which have not invaded Denmark until after 1930 have for a long time been moving northwards in Slesvig and Holstein before they have passed the southern frontier of Denmark. The total number of new species which has immigrated as breeding birds to Denmark in this century is therefore about 25. The large majority of these birds have immigrated owing to climatic factors, but it must be mentioned that some further species have invaded the country owing to other factors such as the planting of coniferous forests which was started in the latter part of the 19th century. These species are naturally not included in the number mentioned.

Finland.

From this country many observations have been made on the changes in the distribution and occurrence of terrestrial animals during recent years, especially with regard to birds and mammals. As will

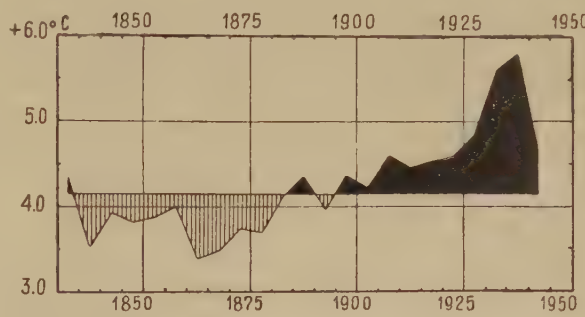

Figure 1. The changes in the annual average temperatures in Helsinki during the last 100 years. (Siivonen 1946).

be seen from Figure 1, giving the annual average temperatures in Helsinki during the last 100 years, it appears clearly that the average temperature has increased very much during this century reaching a maximum about 1930—1938 (Siivonen 1946). In the same period the winter temperatures have increased and several species of birds, which are residents or very early summer visitors and therefore capable of taking advantage of the climatic amelioration in winter and early spring, have increased in numbers. At the same time also the summer temperatures have increased and several southern species have therefore immigrated to Finland as new breeding birds during the first part of this century. As far as I know, however, no general survey of these changes in the avifauna of Finland during the last 50 to 70 years has been published and therefore I am not able to give a statistical report in connection with this phenomenon. Therefore I confine myself to pass some general remarks on the changes in the fauna of Finland, which may be due to the alterations in climatic conditions in the last decades of the 19th century and in this century.

In the central and southern parts of Finland—as

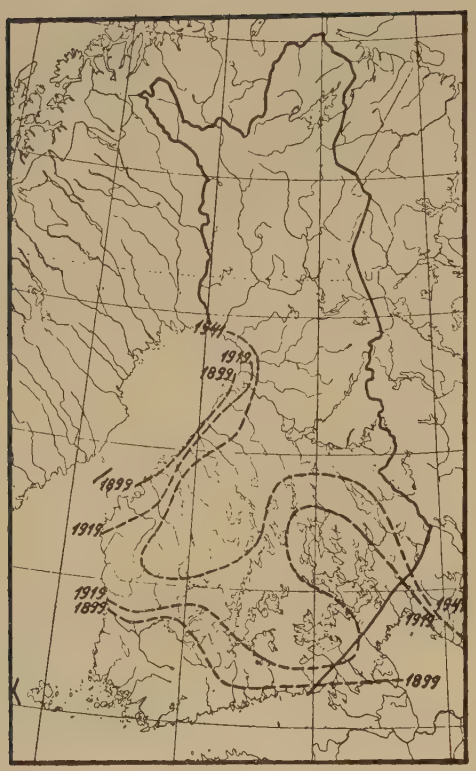

Figure 2. The northern limit of distribution of the Lapwing (*Vanellus vanellus*) in Finland in 1899, 1919, and 1941. (Kalela 1947).

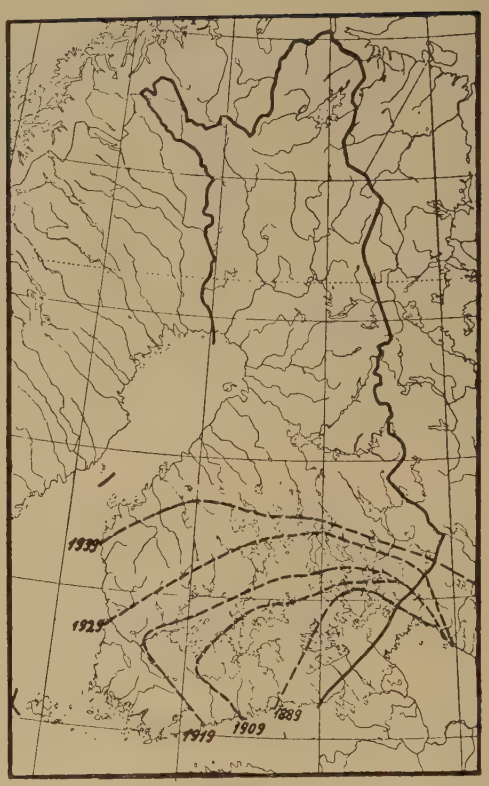

Figure 3. The northern limit of distribution of the Polecat (*Putorius putorius*) in Finland in 1889 and every ten years from 1909 to 1939. (Kalela 1947).

well as in Norway and Sweden—the distribution of a rather large number of birds has moved to the north during the last 50 to 70 years. This means that the northern limit of their distribution is now situated further north than before. As an example Figure 2 shows the northern limit of the distribution of the Lapwing (*Vanellus vanellus*) in Finland in 1899, 1919 and 1941 (Kalela 1947), but for some species of birds the northward movement amounts to several degrees of latitude. This is also the case with some mammals; Figure 3 shows the position of the northern limit of distribution of the Polecat (*Putorius putorius*) in Finland in 1889 and every ten years from 1909 to 1939 (Kalela 1947). It has also been observed that several species of birds reaching their northern limit as breeding birds in Finland have increased considerably during the twenties and the thirties of this century.

Figure 4. The distribution of the Lynx (*Lynx lynx*) in Finland (shaded area) in the years 1880, 1900, 1920, 1940, and 1945. (Siivonen 1946).

Owing to the recent amelioration of the climate in Finland it has further been shown that several northern species now have the southern limit of their distribution further to the north than in the last part of the 19th century. At the same time the number of northern birds has decreased very much in southern and central Finland, if not totally disappeared from this part of the country. The same is the case with some mammals, e. g., the Lynx (*Lynx lynx*)—a northern species—which during the last 50 years has practically disappeared from southern Finland. This will be seen from the maps in Figure 4 showing the distribution (the shaded area) in 1880, 1900, 1920 and 1940; the map for 1945, however, showing again a small increase in southern Finland (after Siivonen 1946).

In Finland it has also been observed that during the recent mild period a number of species, which in earlier times were migratory birds, now very often spend the winter in Finland. At the same time some northern birds, which were previously winter-guests in southern Finland, have decreased very much in this part of the country during this century. Finally I may call attention to the fact that in the first years of the forties, when we had the severe winters (1940, 1941 and 1942) and in the following years, observations have been made which indicate a further change in the bird-life in a more boreal direction.

There are many features of these changes in distribution of terrestrial animals in Greenland, Denmark and Scandinavia which suggest that they may be correlated with the climatic changes in the same period. Undoubtedly, similar changes have occurred in several other countries.

5.

The Forecasting of Climatic Fluctuations and its Importance to the Arctic Fishery.

By

A. J. Lee.

The rise of the Bear Island and Spitsbergen cod fishery since the mid-1920's is said to be associated with the increase of sea and air temperatures in that area. Climatic fluctuations are, therefore, an important factor in the well-being of the Arctic fishery, and, if a cooling of the Arctic regions occurs, it may become necessary to divert the Arctic fishing fleets to other waters.

Trends in climate are well shown by long-period moving means of temperature and a study of such averages shows that a decrease in air temperatures has taken place in NW. Europe since about 1940. Lysgaard (1) has computed the 30-year moving means of temperature for January, July and the year for a number of stations. The January diagrams for Edinburgh, Bodö and Copenhagen all show a downward trend after 1940. Furthermore, the twenty-year moving averages of mean winter temperature at Oxford are at a maximum in the 20 years 1909—28 (2) and Labrijn's climatological record for the Netherlands (3) shows that the maritime climate of recent decades is perhaps tending again in the direction of greater continentality. It is unfortunate that meteorological observations in Spitsbergen were interrupted by the war, because the 5-year moving averages of mean January temperature up to 1941 are at a maximum in the 5 years 1932—37, and it would be interesting to know if the subsequent decline has continued.

Oceanographic observations have not been taken systematically enough to allow the computation of long-period moving means of water temperature, and it is therefore difficult to draw any conclusions about the recent trend of sea temperatures. It must be noted, however, that at various times since 1937 there have been marked fluctuations of temperature in northern waters. Thus, Jensen (4) reported unusually low water temperatures off south-west Greenland in 1937 and 1938, which caused the death of large quantities of cod (*Gadus callarias*) and a decrease in the weight of liver taken from the cod. Furthermore, there were signs of a retreat of Atlantic water at Godthaab during 1942—44 and the amount of winter ice increased (5).

Similar information comes from the waters along the Norwegian coast and the Barents Sea. The drop in temperature in the Norwegian Sea in 1940 was greater than the total rise between 1923 and 1939, but temperatures have subsequently increased (6).

We have recently examined at Lowestoft the bottom temperatures of the fishing grounds around Bear Island. We confined the investigation to the area between the 90 and 200 fathom lines and considered all the observations made since the 1870's of which we have record. It is very difficult to compare sea temperatures that are not all taken in the same position, but in general the temperatures taken west of the 19° E. meridian since 1939 are lower than those taken in the 1920's and 30's. The increase in the amount of ice around Bear Island, since 1940, and especially in the last two winters, seems to be in agreement with this finding. Furthermore, the observations taken by myself in H.M.S. "Cygnet" in the Bear Island area and those taken by Dr. Finn Devold in the same area and off Greenland during summer this year show that, although the upper 100—200 m. of water overlying the banks were colder than normally, the deeper water shows no signs of cooling. My own investigations in the Bear Island area, however, suggest that this water on the banks may have been moving downwards to mix with the bottom water in the deeper Bear Island Channel. Whether this is a normal seasonal phenomenon or one related to the cooling of the upper layers and the increase in the amount of ice awaits investigation.

It would appear, therefore, that there is good evidence of a general downward trend in winter air temperatures over NW. Europe during the last few

years. It is not possible to detect any definite trend in sea temperatures, but the information that we have concerning water temperatures to some extent agrees with the trends deduced from a study of the air temperatures. The problem for immediate consideration is whether this decline will continue or merely be a temporary recession in the general warming of the last few decades.

When considering future fluctuations of climate it must be borne in mind that such changes can take place very quickly. In western Norway, for example, the period of greatest ice advance since the end of the Würm Glaciation is dated about 1745, and the winter of 1740 seems to have been phenomenally cold in NW. Europe. Labrijn's climatological record of the Netherlands, however, shows that the period about 1720 was very maritime, as between 1910 and 1930. Thus, the change in climate in the first half of the 18th century, must have been rapid.

Attempts have been made to forecast fluctuations of climate by searching for periodicities and many cycles of varying length have been discovered. Generally, the amplitudes of these cycles are so small that they might be due to a chance distribution of the observations, and not to truly periodic variations. Moreover, it is well known that most weather cycles, that work well for a time, suddenly stop, and it is necessary to find out the cause of this before we can make any use of periodicity.

It may be possible to forecast the future trend of Arctic climate by obtaining correlations between variations of the meteorological and hydrographical elements in the Arctic and those in other parts of the world. If such formulae are prepared, however, by selecting a few factors out of many, merely because they have an apparent close relationship, the value of all the factors cannot be expected to be maintained. Thus, the value of a correlation coefficient can in reality be much lower than that worked out from a formula. If we seek, therefore, to forecast variations by means of periodicities or correlation, we must adopt sound statistical methods and severe standards.

Only by searching for the physical explanation can we solve the problem of climatic fluctuations. Their cause is now commonly sought in variations in the amount of solar radiation and/or increased atmospheric circulation. The mean temperature of any part of the world is not determined entirely by the heat received from the sun, since it is influenced by the heat transported by the atmospheric and oceanic circulations. Solar radiation supplies the energy required to drive these circulations and any change in the amount of this radiation will modify the circulations. Thus, the effects of a small change of solar radiation lasting over a number of years would be very complex in view of the two-way interaction between the ocean and the atmosphere.

The best way of analysing these effects seems to lie in studying the relation of the changes in the atmospheric pressure distribution to the changes in the amount of solar radiation, once we have sufficient reliable measurements of the latter, and at the same time examining the interaction between the atmosphere and the ocean. Two promising lines of oceanographic research in this field have been started in recent years. Iselin's theory (7) concerning the causes and results of long-period variations in the strength of the Gulf Stream system is an attempt to find a mechanism whereby relatively small variations in the strength of the anticyclone wind-system, and therefore the pressure system, over the North Atlantic can produce a relatively great fluctuation in the transport of warm water to the north-eastern area. Sverdrup (8) has also recently shown that it appears possible to demonstrate quantitatively that the permanent currents are maintained by the permanent winds, and, if so, one may be able to tackle the problem of seasonal and random fluctuations of the currents related to changes in the wind and to processes of heating and cooling.

By studying the interaction between solar radiation and the atmospheric and oceanic circulations along lines such as these, oceanographers may be able to make a most significant contribution to the investigation of the mechanism of climatic fluctuations and to fishery research.

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II.

THE COMPARATIVE EFFICIENCY OF FISHING CRAFT, THEIR GEAR AND MODIFICATIONS OF GEAR

PREFACE

Opening Remarks by Chairman.

THE proposal for a special meeting on comparative fishing came from the Southern North Sea Committee in October 1947 and was in the following terms.

"In view of the importance of evaluating the different methods used, a Special Meeting should be held at the next Council Meeting on the comparative efficiency of fishing craft, their gear and modifications of gear."

Dr. BOROWIK was nominated Convener.

As the time of the meeting drew near, Dr. BOROWIK intimated that, through unforeseen circumstances, he would not be able to attend and asked to be relieved.

After consultation, I as Chairman of the Consultative Committee agreed to take over the responsibilities of Convener and Dr. HAVINGA was appointed Reporter.

The same procedure for the meeting was adopted as at the special meetings in October 1947.

In my opening remarks, I gave a brief outline of the history of the overfishing problem, from the early investigations carried out by the Fishery Board for Scotland down to the international discussions which took place in 1947. These discussions arose out of a proposal by the British Government that in the North Sea and adjacent waters the total tonnage of fishing vessels engaged in bottom fishing, should be limited to 75% of the tonnage employed in 1938. Though all countries were agreed that overfishing was taking place and that the danger had to be remedied, approval of the British proposal for a limitation in the number and tonnage of fishing vessels was not unanimous. For example, some countries favoured instead an increase in mesh, some thought that the capacity and power of vessels should also be taken into account, while others would agree only to a limitation of the catches. Finally it was proposed that certain alternatives to the British proposal might serve as contributions to the overfishing problem. So the matter stands at present. When the convention, signed in 1946, has been fully ratified, an International Commission and/or a Standing Advisory Committee will be set up to take all steps necessary for the regulation and rational exploitation of the fisheries.

As GRAHAM says in his Buckland lectures on Rational Fishing of the Cod of the North Sea, "we have done enough to establish beyond doubt the presence of overfishing and the next step must be to put our estimate of overfishing on a quantitative basis, so that we can say exactly how much overfishing there is, and determine the consequent change in the fishing power needed to adjust the yield to its optimum value."

This then was the purpose of the meeting to collect data on the equivalent effects of different methods of fishing so that the information can be made available when the measures to be adopted for the regulation of the fisheries have to be applied.

The following seven papers were submitted and it is hoped that they will serve as a beginning and help to stimulate further interest in the subject so that the scope of the investigations can be widened considerably.

1) B. HAVINGA and C. L. DEELDER. The relation between the size of meshes of gill-nets and the size of *Lucioperca sandra* in the catches.

2) L. K. BOEREMA. Mesh experiments.

3) AAGE J. C. JENSEN. The relation between the size of mesh and the length of fish released.

4) ARVID R. MOLANDER. Swedish trawling experiments with different cod-end meshes during 1947.

5) A. R. MARGETTS. Experimental comparison of fishing capacities of different trawlers and trawls.

6) A. R. MARGETTS. Experimental comparison of fishing capacities of a Danish seiner and trawlers.

7) B. B. PARRISH. Fishing capacities of gear used by English and Scottish research vessels.

R. S. CLARK.

Reporter's Summary.

THE first four papers deal exclusively with the relation between the size of mesh and the quality and quantity of the fish caught. These papers reveal once more the fact that the size of the mesh is of great influence on the catches. Each size of mesh has a certain selective action in its catching capacity for a special size of fish. This selectivity attains an exceedingly high value in the gill-nets. The straight linear relation between the inner length of the mesh and the fish length at 50% release may prove to be of great practical importance.

In the last three papers, the fishing capacity of complete fishery units, the vessel together with its particular gear, are compared. In the discussions, it was successfully tried to analyse the difference of the diverse elements composing this unit. Of these elements, the following points proved to be of obvious importance:—

(a) the shape of the trawl,
(b) the length of the head rope against the ground rope,
(c) thickness and pliability of the ground rope,
(d) the applying of the towing strain on the head or ground rope,
(e) the working distance between the otter boards,
(f) the thickness of the twine and the material used for its manufacture.

From the papers and the discussions the following conclusions may be drawn.

1) There are great differences in the trawls, commercially used, in all of the elements mentioned above.
2) The difference in the nets used may be explained as being narrow adaptations to the particular conditions of the bottom on which they are fished and to the behaviour of the fish that are the main objects for the particular fishery.
3) The mechanical power of the vessel or its length cannot be used without correction as a measure for its catching capacity.

The experiments were generally considered to be of great scientific and technical importance, and continuation of the experiments would be of great value for the further development of the efficiency of the trawl fishery.

B. HAVINGA.

Conclusions and Recommendations.

THE papers given during the meeting divide themselves into those dealing with comparisons of different fishing vessels which also give incidental information on gear and parts of gear, those which treated with the effect on the catch of different sizes of mesh, and the account of the selective effect of the gill-net.

The investigations of MARGETTS and PARRISH provided factors by which fishing vessels of different types may be compared in respect of their catch and for the different fish species they take. The comparison between these research trawlers and one commercial type showed relative differences of effectiveness for different species which seem likely to be related to different parts of the trawls used, as for instance, when all other parts remained the same but the distance between the boards varied, MARGETTS came to the conclusion that the weight of plaice caught was directly related to this dimension. A number of other comparisons of this sort are desirable and remain to be done.

The relative efficiency of a trawler and a Danish seiner have also been given a numerical relation for a ground which suits a seiner. A resultant problem was the greater catch of small dabs by the trawler compared with the seiner although both vessels had cod-ends of the same mesh size. Here the question posed is, do these small flat fish pass under the seiner's rope, as ROLLEFSEN had observed them to do in a shore seine or can they escape more readily through the flexible cotton-meshed cod-end of the seiner? The Danish seine particularly and some types of light trawl can only be used on certain special grounds, so that the efficiency of such gear must be weighted by the proportion of sea bottom that they can use.

Of the papers dealing with the size of mesh in cod-

ends, those of BOEREMA and MOLANDER support earlier findings that an increased size of mesh may not mean a smaller catch, but that an equal or greater weight of larger fish may be obtained.

In JENSEN's account of mesh selection the straight line relation between the length of the fish and the $50^0/_0$ release point and the different releasing effects of the same mesh under different weather conditions or when made of materials of different flexibility are noteworthy.

Finally the contribution of HAVINGA and DEELDER on the narrow selection of gill-nets brought out in discussion the point that gear such as seines and trawls may be held to have a range of selection of their own, both large and small fish escaping.

A consideration of these papers and the ensuing discussion suggested that further work should proceed along the following lines:—

1) More ship to ship comparisons to obtain relative efficiencies for commercial fishing vessels including
(a) large English North Sea trawlers,
(b) small English North Sea trawlers,
(c) French Channel trawlers,
(d) Belgian motor trawlers,
(e) Danish seiners.

2) Further observations on the effects of different parts of a trawl by
(a) measurements of stresses in different parts of gear by dynamometers,
(b) examination of behaviour of head line and mesh,
(c) study of selective effect of mesh of cod-ends made of different twines,
(d) study of effect of different weights of ground rope and of changed dimensions of ground rope and head line,
(e) measurement of distance between otter doors.

3) Experiments to determine effect of towing trawls at different speeds.

4) Investigation of reactions of fish to the trawl by such means as traps or pockets in different parts of the trawl and by underwater photography.

5) Observations on selective range in drifts-nets.

6) Relation of fishing gears to localities by
(a) determination of areas of sea bottom suited to special nets,
(b) enquiry into distribution of relative quantities of different types of gear in each country.

R. S. WIMPENNY.

1.

The Relation between the Size of Meshes of Gill Nets and the Size of *Lucioperca sandra* in the Catches.

By

B. Havinga and C. L. Deelder

We had the opportunity to study the influence of the size of the meshes on the size of fish caught in experimental fishing of *Lucioperca sandra* (pike perch) in the Ijsselmeer, the former Zuiderzee.

In May 1932 the dike enclosing the Zuiderzee was completed. At that time small numbers of *Lucioperca* were present in the freshest parts. After the enclosure the salinity decreased so rapidly that already towards the end of 1933 the water in nearly the whole of the Ijsselmeer was fresh enough for this fish to live in.

The fish increased very rapidly in numbers so that in the autumn and winter of 1939—1940 3 million kg. were caught. The fishing has, however, been pursued very intensely; in the season 1939—1940 about 80% of the stock was caught. Since this prolific season the catches have dropped sharply; and not until the 1947—1948 season has a catch of more than a million kg. been attained again.

The cause of the great fluctuations in the catches must be sought in the very high intensity of the fishing and in the fact that a successful propagation only occurs in years with a high temperature at the end of May and the beginning of June.

One may be fairly sure that enough food is produced in the Ijsselmeer for a yearly production of a few million kg. As this fish is very valuable, it is of the utmost importance to take such measures as may be required to ensure that this potential catch is obtained as nearly as possible.

The most logical measure would be to restrict the intensity of fishing by limiting the number of fishermen or nets. This, however, cannot be done for different, partly social, reasons.

The idea of increasing the legal minimum size (40 cm.) has also been abandoned after a thorough investigation, although this size is really too low. Owing to the rapid growth the females attain maturity at a length of about 45 cm.; in consequence a very large percentage of the females are caught before they have spawned.

Another possibility to save the females until they have attained maturity would be to prescribe a size of mesh in which these females cannot be caught. As nearly all of the fish are caught in gill nets the measure would be very effective.

This induced us to carry out experimental fishing on a large scale in order to determine whether it would be possible to find a size of mesh that would let through fish of less than 45 cm. and that would retain the fish above that size.

The Experiments.

The nets we chose for our experimental fishing had meshes of 100, 105 and 110 mm. (diagonals of the meshes stretched lengthwise, in wet condition). 25 nets of each kind were used, each with a length of 500 meshes. In order to have the different sizes of mesh evenly distributed over the whole extent of the fished area, not more than 4 nets of the same mesh-size were combined; these sets of 4 nets were alternated with sets of another mesh. All the fish were measured and the weights for each 1 cm. class were calculated from a graph giving the length-weight relationship.

The fishing was carried out from December 1947 to March 1948. The largest numbers of fish were caught in December.

Moreover we had at our disposal the measurements of the catches with 86 mm. and 92—96 mm. nets that are used in the commercial fishing.

The catches with these nets are not comparable, however, quantitatively, as they have been obtained from other localities and with a different number of nets.

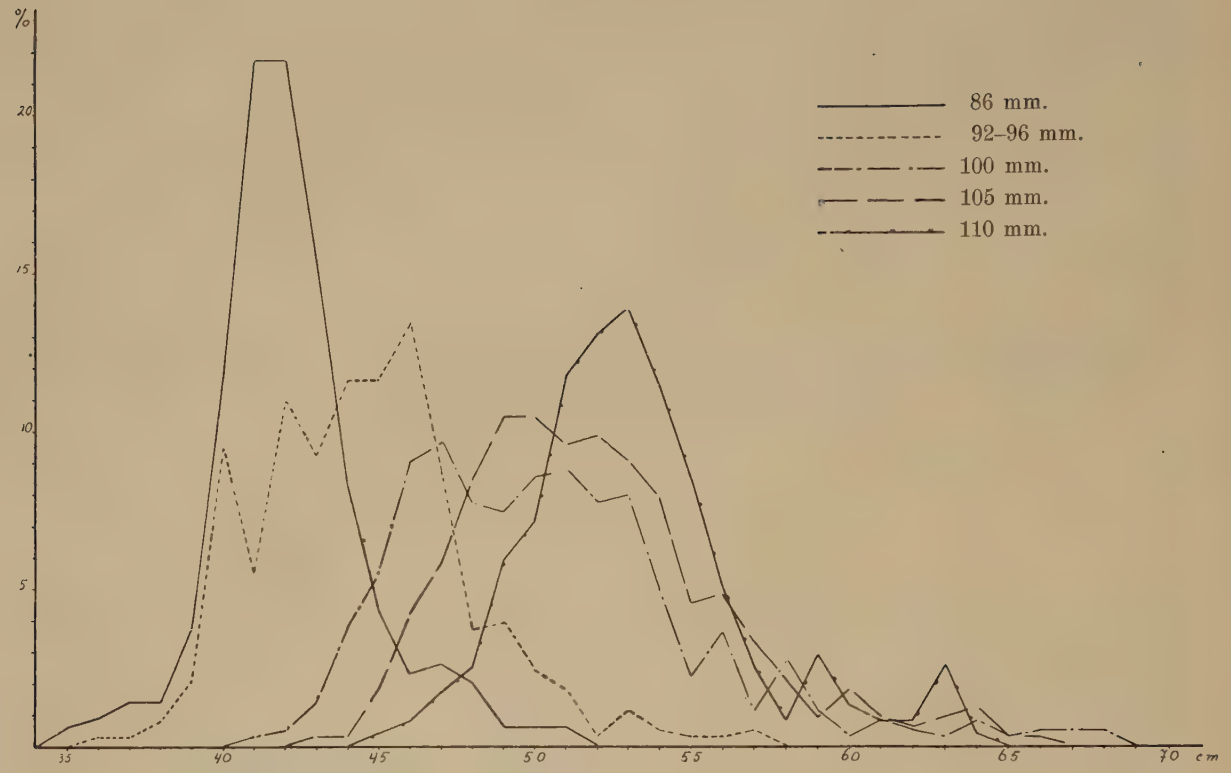

Figure 1. The percentages of length-classes of fish caught in nets of different mesh-size.

Table 1. Length of *Lucioperca sandra* caught in Nets of different Sizes of Mesh.

The figures in the first two columns are not comparable quantitatively with the other ones.

Length of fish cm.	Numbers and percentages (in brackets) of fish caught in nets of				
	86 mm.	92–96 mm.	100 mm.	105 mm.	110 mm.
35	2 (0·6)	—	1 (0·3)	—	—
36	3 (0·9)	1 (0·3)	1 (0·3)	—	—
37	5 (1·4)	1 (0·3)	1 (0·3)	—	—
38	5 (1·4)	3 (0·8)	—	—	—
39	13 (3·7)	8 (2·1)	—	—	—
40	41 (11·7)	36 (9·5)	—	—	—
41	76 (21·7)	21 (5·5)	1 (0·3)	—	1 (0·4)
42	76 (21·7)	42 (11·0)	2 (0·5)	—	—
43	54 (15·4)	35 (9·2)	5 (1·4)	1 (0·3)	1 (0·4)
44	29 (8·3)	44 (11·6)	14 (3·8)	1 (0·3)	—
45	15 (4·3)	44 (11·6)	20 (5·5)	6 (1·8)	1 (0·4)
46	8 (2·3)	51 (13·4)	33 (9·0)	14 (4·2)	2 (0·8)
47	9 (2·6)	33 (8·7)	35 (9·6)	19 (5·8)	4 (1·7)
48	7 (2·0)	14 (3·7)	28 (7·7)	28 (8·4)	6 (2·5)
49	2 (0·6)	15 (3·9)	27 (7·4)	35 (10·4)	14 (5·9)
50	2 (0·6)	9 (2·4)	31 (8·5)	35 (10·4)	17 (7·1)
51	2 (0·6)	7 (1·8)	32 (8·7)	32 (9·5)	28 (11·7)
52	—	1 (0·3)	28 (7·7)	33 (9·8)	31 (13·0)
53	—	4 (1·1)	29 (7·9)	30 (9·0)	33 (13·8)
54	—	2 (0·5)	18 (4·9)	26 (7·8)	27 (11·3)
55	—	1 (0·3)	8 (2·2)	15 (4·5)	20 (8·4)

Length of fish cm.	Numbers and percentages (in brackets) of fish caught in nets of				
	86 mm.	92–96 mm.	100 mm.	105 mm.	110 mm.
56	—	1 (0·3)	13 (3·6)	16 (4·8)	12 (5·0)
57	—	2 (0·5)	4 (1·1)	11 (3·3)	6 (2·5)
58	—	—	10 (2·7)	7 (2·1)	2 (0·8)
59	1 (0·3)	2 (0·5)	4 (1·1)	3 (0·9)	7 (2·9)
60	—	1 (0·3)	1 (0·3)	6 (1·8)	3 (1·3)
61	—	—	3 (0·8)	3 (0·9)	2 (0·8)
62	—	—	2 (0·5)	2 (0·6)	2 (0·8)
63	—	1 (0·3)	1 (0·3)	3 (0·9)	6 (2·5)
64	—	1 (0·3)	3 (0·8)	4 (1·2)	1 (0·4)
65	—	—	1 (0·3)	1 (0·3)	—
66	—	—	2 (0·5)	1 (0·3)	3 (1·3)
67	—	—	2 (0·5)	—	—
68	—	—	2 (0·5)	1 (0·3)	1 (0·4)
69	—	—	—	—	3 (1·3)
70	—	—	1 (0·3)	1 (0·3)	2 (0·8)
71	—	—	—	1 (0·3	1 (0·4)
72	—	—	1 (0·3)	—	—
73	—	—	—	—	—
74	—	—	2 (0·5)	—	2 (0·8)
75	—	—	—	—	1 (0·4)

In Table 1, the results of our fishing experiments are shown, to which are added the catches of the commercial 86 mm. and 92—96 mm. nets. The percentages of the frequencies of the length-classes of fish which have been calculated from the figures in Table 1 are shown in Figure 1.

Especially from the graphs it is obvious that the size of mesh has a very sharp selective action. Each graph has a distinct top, and at both sides of the top the slopes are rather steep. The length of the fish caught by preference by each net extends over only a few cm. This interval we shall denote as the optimal length of the fishes for each size of mesh. As the limits for this optimal length we shall arbitrarily take the frequency of 5%.

The ascending part of the graph is steeper and more regular than the descending part, especially at the extreme ends. This can easily be explained. The small fish can escape as soon as the difference between the circumferences of the fish at its maximum and of the mesh has a certain value, that need not to be very great, whereas a large enough fish can be hold fast in a mesh by different parts of its body, beginning with the head where the protuding bones of the maxillae or the pre-operculum can make a retreat impossible, and ending at about the middle of the body where the circumference is generally at its maximum. Moreover in the fine linen gill nets in use for the catching of *Lucioperca* a large fish may also be entangled in a great number of meshes that forms a pocket. It is, therefore, obvious that a graph indicating the relation between the frequency and the lengths of the fishes in a certain net must have a rather steep ascent and a slow descent.

The close correlation between the size of the mesh and the length of the fish caught implies that with the commercial nets that are generally used only very few large fish are caught.

In Table 2 the optimum lengths of the fishes and the central value between the limits for the different kinds of nets are shown together with the length of the fish at their maximum frequency.

Table 2. Optimum Fishing Capacity of Gill Nets of different Size of Mesh.

Size of Mesh in mm.	Optimum Length of fish in cm.	Central Value of opt. Length in cm.	Length at max. frequency in cm.
86	39—45	42	41·5
92—96	39·5—47·5	43·5	46
100	45—54	49·5	47
105	46·5—54·5	50·5	49·5
110	49—56	52·5	53

If a graph (Fig. 2) is constructed of the central values of these optimum sizes in relation to the size of mesh, a straight line will best fit the points obtained.

It is obvious that these points will give a truer value for the optimum size than the top of the graph, for the shape of the graph is a function, both of the size of mesh and of the relative frequency of the length-classes of the fish. The tops of the graph only coincide with the mean values if the distribution of the length-classes is of equal strength. This, however, will not usually happen.

That there is no great difference between the figures for the central value and the lengths at the maximum frequency (top of the graph) is caused by the fact that the frequency distribution of the medium and large-sized fish was indeed equal, as will be shown later on. The high peak to the graph for the 86 mm. nets is caused by a great frequency of fish of 41 and 42 cm. which length coincides with the optimum length caught by the 86 mm. nets.

As the fishermen were aware of the great abundance of the 41 and 42 cm. fish, they changed from their 92 mm. nets to the 86 mm. nets, as these were more efficient for this length of fish. In this case we see a deliberate adaptation of the size of mesh to the most frequent size of fish.

The straight line in Figure 2 enables us to determine for each size of mesh the length of the fish that will be caught by them in largest numbers, while the hatched area indicates the limits of the optimal length. Of course the fishermen act empirically but the line would provide them with the means to select the most efficient net for each length-class of fish.

The practical results of the experiments with the nets that can be compared quantitatively were that 420 kg. pike-perch were caught with the 100 mm. mesh, 430 kg. with the 105 mm. mesh and 340 kg. with the 110 mm. mesh.

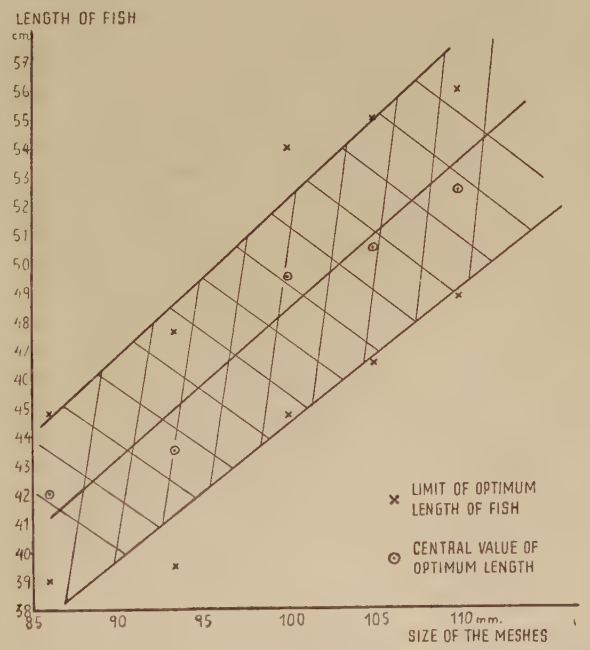

Figure 2. The optimum length of fish in relation to the size of mesh.

The use of a series of different sizes of mesh offers an opportunity to estimate the relative frequency of the different length-classes of the population at that time, provided that the quotient of the total numbers of fish present at the optimum length, and the numbers of fish caught at that length is the same with each size of mesh.

In our case we are only able to make use of the meshes of 100 mm., 105 mm. and 110 mm. with which we fished simultaneously. If we select for each of these nets the numbers caught at the lengths with a frequency of at least 8% in the catches (Table 3) we see that in the 100 mm. net the number of fish caught in each cm.-class varies from 28 to 35 (mean number 30·5) in the 105 mm. net from 28—35 (mean number 32) and in the 110 mm. net from 20—33 (mean number 28). These figures represent—under the restriction made—the relative frequency of the fish at each cm.-class.

From the figures in Table 3 it is evident that during the period of the experiments the number of fish from 46 cm. to 54 cm. were very constant while at 55 cm. the number diminishes. This result was quite unexpected and contrary to the general opinion, as the large fish are relatively rare in the commercial nets. Lack of measurements of catches with nets with small meshes makes it impossible to calculate the frequency of the small fish.

Table 3. Number of Fish in the cm.-classes, occurring in a frequency of at least 8 per cent., caught with Nets having Meshes of 100, 105 and 110 mm.

Length of Fish cm.	Numbers of Fishes in Nets of:		
	100 mm.	105 mm.	110 mm.
46	33	—	—
47	35	—	—
48	28	28	—
49	27	35	—
50	31	35	—
51	32	32	28
52	28	33	31
53	29	30	33
54	—	—	27
55	—	—	20
Mean numbers	30·5	32	28

2.

Mesh Experiments.

By

L. K. Boerema

From 9th -11th July 1947 a comparative fishing experiment was made between the "Platessa", the research vessel of the Fisheries Laboratory at Lowestoft, and two Dutch cutters. The "Platessa" used the typical English gear, the cutters the gear they normally use on their fishing grounds, but one with a cod-end of 74·0 mm. (the TX 14) and the other (the TX 39) a cod-end of 53·0 mm. mesh size. We only need to consider the two cutters here.

The cutters were of the same type, 21 metres long, using 150 b.h.p., the headlines of the nets were about 100 ft. The ships fished as near each other as possible and shot and hauled together.

Table 1 shows the quantities of the different species caught in each haul. Eleven hauls were made. The quantities could only be estimated. In order to control the estimations the total quantities as weighed on the market are added. (See Table 1 overleaf.)

Table 2 shows the quantities landed of the different market categories by the two ships.

In general there is no big difference between the catches of both ships. The total catch was nearly equal, in the catches of the different species there are slight differences.

Table 2. Cruise 9th—11th July 1947.

Species	Market Category	TX 14	TX 39
Plaice.....	> 35 cm.	48 kg.	58 kg.
	27—35	126 ,,	129 ,,
	21—27	389 ,,	330 ,,
Sole	> 32 cm.	138 ,,	121 ,,
	29—32	47 ,,	62 ,,
	26—29	14 ,,	18 ,,
	23—26	3 ,,	8 ,,
	15—23	— ,,	12 ,,
Turbot.....	> 4 kg.	39 ,,	22 ,,
	2—4	36 ,,	22 ,,
	1—2	23 ,,	15 ,,
	< 1 kg.	28 ,,	46 ,,

The market values of the catches landed were nearly the same, the TX 14 making f. 805, the TX 39 f. 781.

The figures obtained do not permit of further analysis.

Table 1. **Cruise 9th—11th July 1947. (Quantities in Kg.)**

	Station	Date	Time of Shooting	Dur. of haul	Plaice	Gurnards and Dabs	Soles	Whiting	Turbot and Latchets	Horse-Mackerel	Total
		July 1947	h.	m.							
TX 14.....	1	9	15.30	2.55	50	35	9	6	18	35	153
TX 39.....	1	9	15.10	3.05	44	15	15	15	30	41	160
TX 14.....	2	9	18.40	3.00	35	17	25	40	20	5	142
TX 39.....	2	9	18.30	3.00	26	15	20	23	23	14	121
TX 14.....	3	9	22.00	2.55	100	15	45	18	10	1	189
TX 39.....	3	9	21.40	3.20	70	15	40	30	30	14	199
TX 14.....	4	10	2.00	2.55	60	15	35	7	35	—	152
TX 39.....	4	10	1.20	3.15	70	15	40	15	7	27	174
TX 14.....	5	10	5.10	3.00	30	10	20	20	22	8	110
TX 39.....	5	10	4.40	3.20	44	15	25	15	23	2	124
TX 14.....	6	10	8.45	4.15?	50	16	5	3	14	—	88
TX 39.....	6	10	8.25	3.15	17	15	5	8	7	5	57
TX 14.....	7	10	13.15	2.15?	50	18	2	0·5	6	—	76·5
TX 39.....	7	10	12.05	3.10	44	5	5	2	15	—	71
TX 14.....	8	10	16.00	3.15	80	9	5	1	13	—	108
TX 39.....	8	10	15.50	3.10	70	15	8	—	15	—	108
TX 14.....	9	10	19.30	3.15	40	11	18	0·5	7	5	81·5
TX 39.....	9	10	19.30	3.20	26	15	20	—	15	41	117
TX 14.....	10	10	23.00	3.30	30	16	20	—	13	—	79
TX 39.....	10	10	23.10	3.00	26	15	25	—	15	—	81
TX 14.....	11	11	4.00	2.50	30	11	5	0·5	13	0·5	60
TX 39.....	11	11	2.30	3.10	35	15	10	—	7	—	67
TX 14 .... / TX 39	Total Stations 1—11 ..		34.05		555	173	189	96·5	171	54·5	1239
			35.05		472	155	213	108	187	144	1279
TX 14 .... / TX 39	Total weighed at market		563		160	202	95	212	72		1341[1])
			517		134	221	137	182	158		1393[2])

		TX 14	TX 39		TX 14	TX 39
Weighed at market....	Gurnards	83	81	Turbot	127	105
	Dabs	75	53	Latchets	85	77

[1]) Including: 5 Brill; 12 Mullet; 11 Weavers; 6 Cod.
[2]) — : 2 — ; 16 — ; 15 — ; 13 — ; 2 Mackerel.

3.

The Relation between the Size of Mesh and the Length of Fish Released.

By

Aage J. C. Jensen

The most common, and no doubt also the most practical, method for estimating the selective action of a net is that used by Todd *et alii* to give the length at which 50% of the fish are released (or retained), the "critical point" acc. to Buchanan-Wollaston[1]).

The "Law of Chance Selection" says that the selection curve is a S-shaped ogive in the central part corresponding to the normal Curve of Error[2]), but it is a general rule that the ogive is somewhat more flattened towards the left-hand side than towards the right. It is astonishing how much the sharpness of the selection differs not only in the various experiments but also for the various species in a single experiment. The 25% and 75% points of release may in most cases be some 7—15% below and above the length at which 50% are released. As a general rule it may be said that the selection found for the flat fish tends to be somewhat more sharp than that found for the round fish.

Part of the difference in the shape of the selection curve is undoubtedly due to faults in the material, while in many experiments in one or both series the upper and lower parts of the curve are derived from only a few specimens in one or both of the two series. In some nets the size of the meshes is very uniform while in other nets the size may vary considerably.

In practice it is essential that the actual size of the meshes, i. e. their inner length, and also the material used should be stated. Very often only the number of knots per yard or per m. is stated, and although it is possible for instance from Davis' Table XVI[3]), or Figure 1 in this paper, to find the corresponding inner size of the meshes, this indirect method is very inaccurate especially where the material of the net is not stated.

The inner length of the mesh is of course the size which has the greatest bearing on the releasing effect but also the stiffness or flexibility of the material plays a very great rôle, especially for the flat fish. A minor fault may be introduced by using figures for the length of the fish measured to the nearest lower cm. without adjusting by + 0·5 cm. when comparing with adjusted figures.

Borowik has proved that considerable numbers of fish escape from the front, side and underside of the trawl and that it is not quite sufficient to compare the releasing effect of the cod-end meshes only[4]). On the other hand Clark has shown that the wings of a seine are of secondary importance where escapes of flat fish are concerned and that escapes are effected mainly through the bag and the cod-end[5]). In laws regulating the mesh size it should always be stated that the minimum size imposed should concern all parts of the net, but even if in some cases it should be practical to regulate the cod-end meshes alone the fishermen would hardly be able to diminish the releasing effect very much by using smaller meshes in the front part of the net.

In this paper the effect only of the size of mesh in the cod-end has been considered.

Todd has also shown that the weight or bulk of the catch and the conditions of the sea have some influence on the selective effect, namely a large catch, or a calm sea tend to raise the sizes at which, e. g. 50% are retained, while a rough sea or light catch have an opposite effect. As stated by Borowik the speed and other factors may also have some influence.

[1]) H. J. Buchanan-Wollaston: Inshore Trawl Fisheries of Dorset and Devon. Fish. Invest., Ser. II, XIII, 1. 1933

[2]) H. J. Buchanan-Wollaston: On the selective Action of a Trawl Net, with some Remarks on selective Action of Drift Nets. Journ. du Cons., II, 3. 1927.

[3]) F. M. Davis: Mesh Experiments with trawls 1928—1933. Fish. Invest., Ser. II, XIV, 1, 1934. (The heads of the columns XI and XII of Table XVI are exchanged.)

[4]) J. Borowik: On what does the Catch of undersized Fish depend? Journ. du Cons., V, 2, 1930.

[5]) R. S. Clark: Scottish Seine Net Investigations. Rapp. et Proc.-Verb., Vol. XC, V, p. 57, 1934.

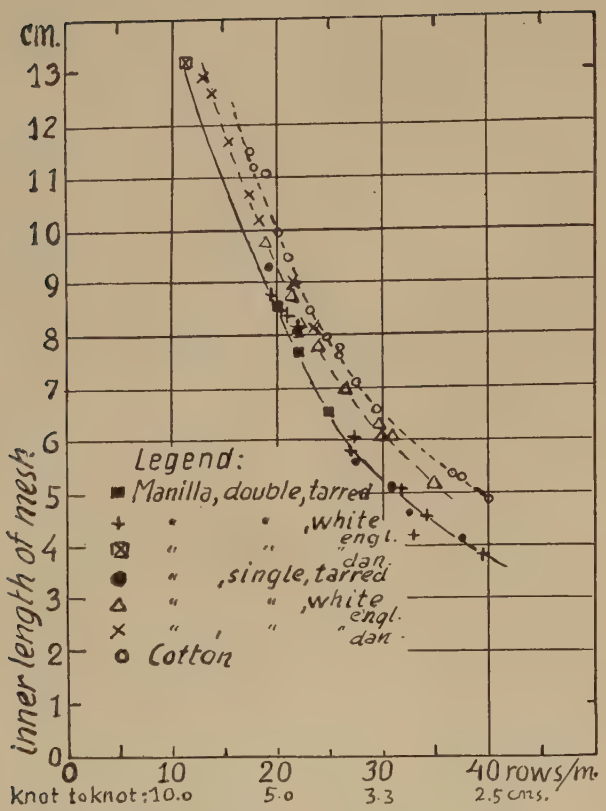

Figure 1. Relation between inner length of mesh and rows of knots per m. as found by DAVIS (Fish. Invest. Ser. II. Vol. XIV, 1), IVERSEN (Rapp. et Proc.-Verb. XC, III) and the present writer.

As yet we have no material permitting a quantitative estimation of these modifying factors.

The methods for determining the number released are:

1. Fishing with a small-meshed covering net.
2. Fishing with a trouser trawl.
3. Alternating or simultaneous hauls with small-meshed and large-meshed cod-ends.

The lengths at which 50% are released has been shown in Fig. 2. The sources of material have been given at the end of this paper.

It appears from Fig. 2 that the covering net experiments show a straight line relationship between the inner length of the cod-end mesh and the length at which 50% are released.

This fixed relation $c = \frac{l}{m}$, between the length (l) of the fish at which 50% are released, and the inner length (m) of the mesh I have called the relative releasing effect. The size of the factor may be found from Figure 2 to have approximately the following values:

	Plaice	Dab	Cod and Haddock	Whiting	Hake and Sole
c =	2·0	2·2	2·9-3·1	3·1	3·5

Also all the results of the various experiments with a trouser trawl and with simultaneous and alternating hauls published up to the present are shown in Figure 2. It will be seen that most of the results from these experiments agree completely with the results from the covered net experiments.

The investigations made by K. A. ANDERSSON[1]) with a trawl having a cod-end with meshes of 4. cm. from knot to knot also seem to give a relative releasing effect not very much higher than those of the covered net experiments, since the corresponding inner length of meshes according to the accompanying Figure 1 may have been about 6·6 cm. and it is seen from Dr. ANDERSSON's figure p. 61 that a 50% release of haddock must have occurred at about 21 cm. length.

On the other hand some other experiments have given relatively greater lengths where 50% were released.

From the greater lengths found for haddock by a "commercial experiment" with alternating hauls compared with covered net experiments DAVIS came to the conclusion "that the results of the covered mesh experiments must be entirely neglected (except as a basis for comparing the releasing factor of various fishes)" as a means for estimating the real releasing effect of the cod-end on account of the masking effect of the cover[2]). On the other hand DAVIS points out (loc. cit. p. 27) that a control experiment with covered cod-ends (alternating hauls with covered and uncovered cod-ends) showed that the practical effect of the errors caused by the masking effect of the cover was small since the length at 50% released was about the same in the two series of hauls. The present writer believes that the result of the "commercial experiment" may be somewhat dubious since it cannot be seen from the paper whether it was determined that there was a sufficiently dense stock of small fish on the ground worked during the experiment. If there were only few small fish this explains the great length found for the 50% release point.

Also some of the other results with alternating hauls may be subject to errors. Thus perhaps, some of BOROWIK's results, since it is not quite clear if all the catches he compared really came from exactly the same fishing ground. As mentioned above BOROWIK's results with inner mesh sizes of 8·3 cm. and 8·6 cm. correspond to those of the covered net experiments, whereas for an inner mesh length of 7·9 cm. a relatively high length at 50% release is found.

Only the experiments of RUSSELL and EDSER with meshes of 10 cm. inner length and of BOWMAN with meshes of 8 cm. might seem strictly to confirm the

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[1]) K. A. ANDERSSON: Experiments with Trawls having different meshes in the cod-end. Rapp. et Proc.-Verb., Vol. XC, VI, p. 59, 1934.

[2]) F. M. DAVIS: Mesh Experiments with Trawls 1928—1933. — Fish. Invest. Ser. II, XIV, No. 1, p. 27, 1934, (cp. also p. 34.)

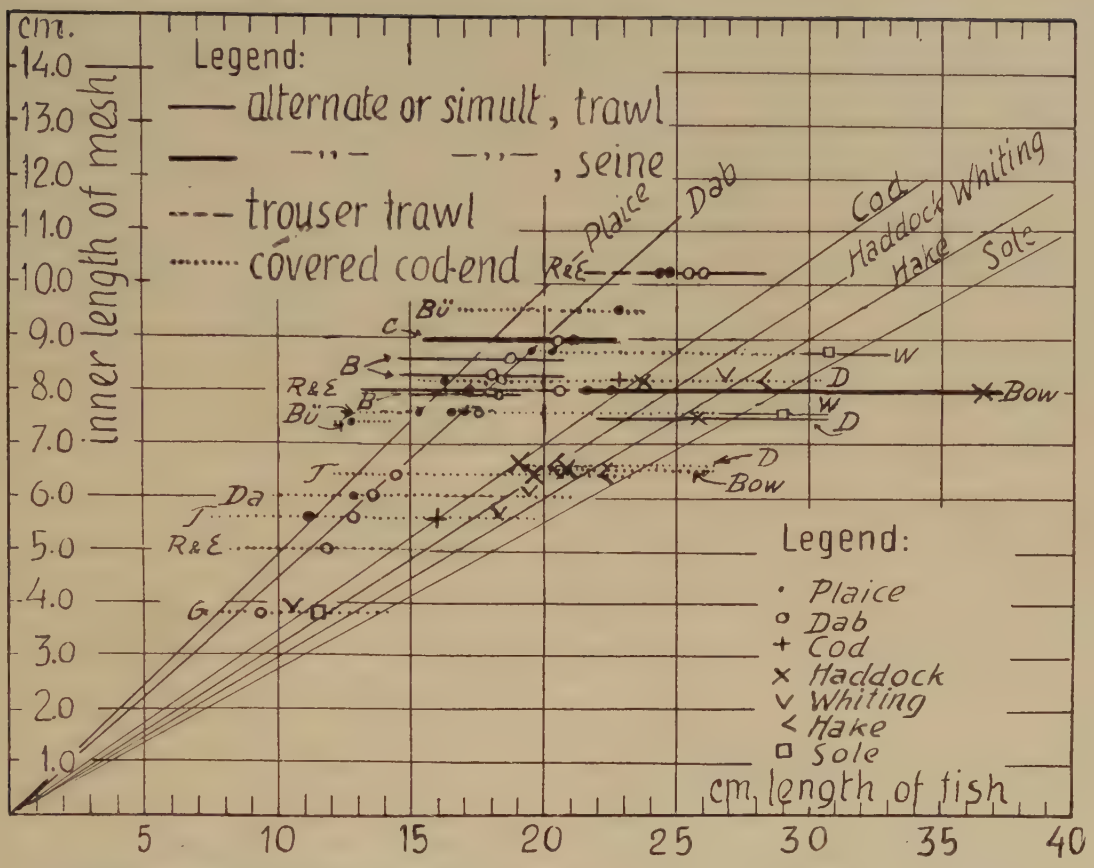

Figure 2. Relation between inner length of mesh and length at which 50% are released. B: Borowik; Bow: Bowman; Bü: Bückmann; C: Clark; D: Davis; Da: Danish (Horns Reef Area 1936); G: Gilson; R & E: Russell and Edser; T: Todd; W: Buchanan-Wollaston. Real length of fish (corrected by + 0·5 cm. when measured to the nearest lower whole cm.).

conclusion made by DAVIS. Yet another explanation may seem more justified.

It is remarkable that these experiments which show with absolute certainty relatively high lengths at 50% release are made partly with the Danish seine with meshes of thin and flexible material, partly with the largest trawl meshes investigated of single twine and used white, i. e., quite flexible.

One should expect small meshes of stiff hemp to have a relatively much smaller selective effect than large meshes of the same material and also cotton nets of the same inner mesh length to have a much higher selective effect than nets of hemp, especially for flat fish. The opening of the small meshes of stiff material will tend to be square while all meshes of cotton can easily be stretched longitudinally and also the larger meshes of hemp can easily change their form according to the section of any fish which is trying to escape. The maximum ratio for the escape of a flatfish between the selective effect of a mesh which can be stretched longitudinally and a square mesh of the same inner length is naturally the ratio of the length of the stretched mesh to the diagonal of the square mesh, i. e., 2:2 1/2 = 1·4 or 140%. In BOWMAN's experiment with an 8·0 cm. inner mesh length the length of plaice at 50% release is 130% of that found for the trawls, but his length of haddock is 150% higher than that of trawls. For round fish one should not expect any very great difference and something must therefore be wrong, and new experiments are needed.

The experiment of CLARK using a whitefish seine with an inner mesh length of 9 cm. did not show any greater releasing effects for plaice and dab than those corresponding to the linear relationship obtained from the trawl experiments with meshes up to this size (vide Fig. 2).

The greater selective effect of the meshes of flexible material used in the Danish seine seems to be confirmed by measurements (made by the present writer) of the lengths of plaice caught in Danish seines of various mesh sizes at Thyborøn in April 1948. Unfortunately it has not been possible simultaneously to state the actual number of fishes present on the

ground worked and of smaller length than those caught in the Danish seines, but the fishing was carried out on grounds where these small fish normally are abundant and quantitative fishing experiments partially on the same grounds about a month later showed that this was the case. From the lengths of plaice retained in the Danish seine the following minimum lengths of plaice at 50% released can therefore be estimated:—

inner mesh length ..	6·5	7·0	7·5	10·0 cm.
50% plaice released.	16·5	17·5	20·0	23·5 cm.

On account of their uncertainty these figures have not been given in Figure 2, but it is seen that they show a higher relative selective effect than the trawl experiments.

The most important results of the investigations are:

1) A linear relation between the inner length of the mesh and the fish length at 50% released by trawl cod-ends is found by the experiments with mesh lengths of up to about 9 cm. Larger trawl cod-end meshes seem to have a somewhat higher relative releasing effect.

2) Seines of more flexible material tend to have a higher relative releasing effect than trawls.

3) We do not as yet know so very much about the lengths at which 50% are released by a trawl with cod-end meshes corresponding to a 100 mm. broad gauge which the London Conference of 1946 (amended in 1947), has fixed as a minimum mesh for the North Sea, Skagerak and Kattegat, and we know still less about the larger minimum mesh fixed for the northern waters. It might seem as if the minimum mesh fixed for the North Sea retains more than 50% of plaice, cod and haddock (minimum lengths 26—27, 35 and 32 cm. respectively), and less than 50% of sole and whiting (27 and 20 cm., respectively).

Sources of Material.

Borowik: Journ. du Cons. V, p. 197. Simultaneous hauls with cutter trawls:

1) local trawls with 30 and 40 mm. cod-end meshes of thin cotton.

2) common cutter trawls with 43 and 45 cod-end meshes, presumably of hemp. The mesh lengths mentioned, being distances from knot to knot, correspond to inner lengths of 6·0, 7·9, 8·3 and 8·6 cm. respectively. The critical length has been calculated from Table II, *loc. cit.*

Bowman: Rapp. et Proc.-Verb. LII, No.11:

1) Covered-net experiments with commercial otter trawl. Cod-end of double twine, 3—3$^1/_2$ inch mesh, acc. to Fig. 1 of the present paper corresponding to about 6·5 cm.

2) Simultaneous hauls with small-meshed trawl and Danish seine with cod-end meshes 3—3$^1/_4$ inch diagonally from knot to knot, i. e., about 25·2 rows/m. Length of plaice calculated from tables *loc. cit.*, p. 231; for Sept. 1924 it has been supposed that "number caught below any given size", e. g. below 12 cm., means below 120 mm. It is not quite clear if the catches by trawl and Danish seine are from precisely similar positions. The total stock on the ground has been estimated graphically from the trawl catch (calculated directly from the catch in the trawl, the length at 50% release is 1 cm. less in both of the experiments).

Buchanan-Wollaston: Fish. Invest., Ser. II, XIII, No. 1. Small inshore trawls with cod-ends of 3 inch and 3$^1/_2$ inch meshes, respectively of salmon ply, single. I have assumed that these mesh lengths are double distances from knot to knot as stated for the trouser trawl used 3 years previously. Then the corresponding inner length of mesh is 7·6 and 8·8 cm., respectively.

1) Covered-net experiments (for plaice and dab) and

2) alternating hauls (for sole).

3) Trouser-trawl experiments, the larger-meshed leg with double distance from knot to knot 3 inches, i. e., 7·6 cm. inner length of mesh. The critical length for plaice is here 17·1 cm. (shown in Fig. 2).

Bückmann: Rapp. et Proc.-Verb. LXXX, VII. Covered-net experiments:

1) With commercial trawl cod-end 20 rows/m. of 2$^1/_2$ mm. manilla, double, with inner mesh length supposed to be 7·4 cm., while it is stated that the length was smaller than in experiment 2.

2) With cutter trawl with sole cod-end, 24 rows/m. 2$^1/_2$ mm. manilla, single, acc. to my Fig. 1, 7·6 cm. inner mesh length.

3) With cutter trawl with cod-end for plaice 21 rows/m. 1$^3/_4$ mm. manilla, single, acc. to Fig. 1, 9·5 cm. inner mesh length.

Clark: Rapp. et Proc.-Verb. XC, V. Simultaneous hauls with small-meshed otter trawl and Danish seine (whitefish seine) with inner mesh length 3$^1/_2$ inch or 8·9 cm. in cod-end. No results of covered-net experiments mentioned in the paper have been published in such a form that the percentage escapes can be calculated.

From the seine with 8·9 cm. inner length of cod-end meshes 50% of plaice of 20·5 cm. length escape, acc. to the table *loc. cit.* p. 57, corresponding to a maximal breadth of the fish exclusive of marginal fins of 7·82 cm. Consequently the breadth of the plaice exclusive of marginal fins at 50% escapes is about 12% less than the inner length of the cod-end meshes. For trawls the corresponding breadth of the plaice is about 20% less than the inner mesh length of the cod-end.

Danish experiments at Horns reef in 1936. 50 feet otter trawl with covered cod-end, measurements of the meshes by the present author; unpublished material.

Davis: a) Fish. Invest., Ser. II, XIV, No. 1 and b) Rapp. et Proc.-Verb. XC, I, Appendix B, p. 14 and D, p. 27:

1) Covered-net experiments with commercial trawl, cod-end 8 cm. spool, white, double, according to Fig. 1 of the present paper 6·6 cm. inner mesh length. Results are published only for hake (*loc. cit.* a, p. 20). Davis mentions (*loc. cit.* a, p. 5) that this mesh size, the normal in 1932, appears to release 50% of haddock at about 19 cm. This value has been shown in my Fig. 2.

2) Covered-net exp. with comm. trawl. "10 cm." cod-end mesh of double manilla, white 100's, 18—21 rows/yard or ca. 21·9 rows/m., according to my Fig. 1 8·2 cm. inner mesh length.

3) Simultaneous hauls with commercial trawls, 20·73 rows/yard (22·7 rows/m.) and 23·70 rows/yard, respectively ("commercial experiment"). Both nets were tarred, and

we must suppose that the net of the cod-end was double. The inner mesh length of the larger-meshed cod-end has been 7·5 cm.

KYLE: Rapp. et Proc.-Verb. IV, p. 100 (material from GILSON). Covered-net exp. with small beam trawl with 2—2·5 cm. mesh or 50—40 rows/m., respectively. From my Fig. 1 the inner mesh length is found to be between 3·5 and 4·0 cm.

RUSSELL and EDSER: Journ. du Cons. I, p. 39:
1) Covered-net exp. with commercial otter trawl, inner length of mesh stated, 5·0 cm. (double twine, tarred).
2) Trouser-trawl exp., cod-end meshes 8 cm. and 10·2 cm. (single twine, white) of the two legs respectively. I have treated this exp. also as a fishing exp. with alternate hauls, comparing with the stock found by the covered trawl. The 10·2 cm. mesh by reckoning from alternate hauls gives the higher of the values for plaice and dab shown.

TODD: Marine Biol. Assoc. of the United Kingdom, International Fishery Invest., Rep. III, 1906—8 (1911), p. 177:
1) Otter trawl with covered cod-end.
2) Beam trawl with covered cod-end. Inner mesh lengths acc. to DAVIS *loc. cit.* a, p. 5 is 5·6 and 6·4 cm. respectively. Critical lengths from TODD's figures. The results are cited by DAVIS (*loc. cit.* a) but there the figures for dab and whiting are exchanged while the same exchange is found in TODD's paper—cp. TODD's tables and text.

4.

Swedish Trawling Experiments with Different Cod-End Meshes during 1947.

By

Arvid R. Molander

Owing to very limited possibilities for work at sea only a few trawling experiments to examine the effect of mesh sizes on the trawl catches could be carried out from Sweden during 1947.

In the experiments a 90-foot trawl of a modern type (otter-trawl) with a cod-end mesh size of 80, 90 and 100 mm. respectively was used.

During the short time at our disposal it was very difficult to fish in areas with a fairly abundant stock of fish, and the quantity of the catches was thus not sufficient to draw any general conclusions from the results. The poor stock of fish also made it necessary to go to places where only certain species could be found. The investigations were therefore concentrated on trawlings for cod, haddock and whiting.

Cod.

The trawlings for cod have been carried out from the 25th to the 29th September 1947 north and north-east of Bornholm at a depth of 75—80 m.

In Figure 1 I have shown graphically the catches from the experiments with different trawls. The length distribution is shown in 5 cm. groups.

It appears from the figure that the increase in the size of the fish caught corresponded with the increase in the mesh from 80 mm. to 100 mm. The differences are evident, but not very great. During the period of the experiments the stock of cod was very uniform and individuals under 30 cm. rare, a fact which was established by simultaneous trawling with finer-meshed gear. The experiments show moreover that trawls with larger meshes give also quantitatively better catches. Thus the catches of cod per one hour's trawling with a 100 mm. mesh net were 43% greater than with a 80 mm. mesh net. If this result is confirmed by continued fishing experiments the matter ought to be considered by the fishing industry.

Haddock.

Owing to the great scarcity of haddock in the waters near Sweden at the end of October 1947, the trawling for this species had to be transferred to the North Sea and the neighbourhood of Ling Bank—Fladen Ground, at a depth of 89—92 m. Owing to the weather conditions the number of trawlings was limited.

In Figure 2 curves are given showing the composition of the catches. The length distribution is shown in 5 cm. groups. The results of the trawlings are, however, not sufficiently reliable to give an answer to the question of the difference in catch composition in trawls with 80 and 90 mm. cod-end meshes

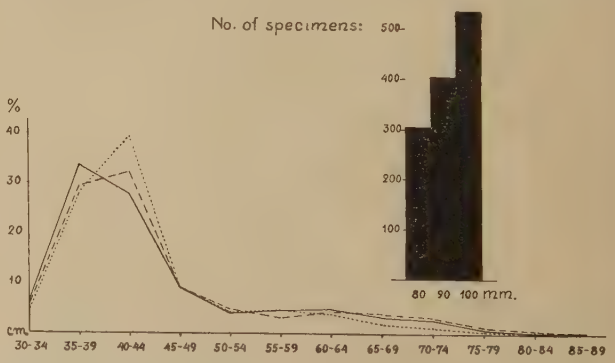

Fig. 1. The Percentage Length Distribution of Cod in captures from the southern Baltic, Sept. 1947, with trawls of different mesh sizes.

Catches with cod-end meshes of 80 mm. ————.
— - — — - 90 mm. - - - - - - - - -.
— - — — - 100 mm. ·····.

The black columns give the number of cod per 1 hours' trawling with 80, 90, and 100 mm. cod-end meshes.

respectively. Catches in trawls with a cod-end of 90 mm. meshes thus contain proportionally a greater number of haddock between 25—29 and 30—34 cm. than catches in a trawl with a cod-end of 80 mm. meshes. But the number of trawlings is really too small to give a correct picture.

On the other hand the difference between the catches in the above-mentioned trawls and the trawls with 100 mm. meshes is very definite. But the size of the individuals caught per hour has at the same time decreased so greatly that it could scarcely be compensated for by the better quality.

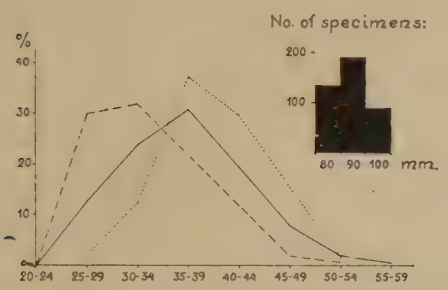

Fig. 2. The Percentage Length Distribution of Haddock from fishing experiments on the Fladen Ground-LingBank, Oct. 1947, with trawls of different mesh sizes.

Catches with cod-end meshes of 80 mm. ————.
— - — — - 90 mm. - - - - - - - - -.
— - — — - 100 mm. ·····.

The black columns give the number of haddock per 1 hour's trawling with 80, 90, and 100 mm. cod-end meshes.

Whiting.

In Figure 3 are shown the results of 4-hour fishing for whiting in trawls with 80 and 100 mm. cod-end meshes respectively. The trawlings were carried out in July 1947 west of the Skagerak at a depth of 130—180 m.

The catches were relatively small. From the graphs, however, a distinct difference is apparent between the composition of the catches in the different trawls. But the catches of whiting in the larger-meshed trawl were very small, therefore presumably a good number of the larger whiting must have escaped from this trawl.

The trawling experiments are, however, not sufficiently numerous to permit of reliable conclusions.

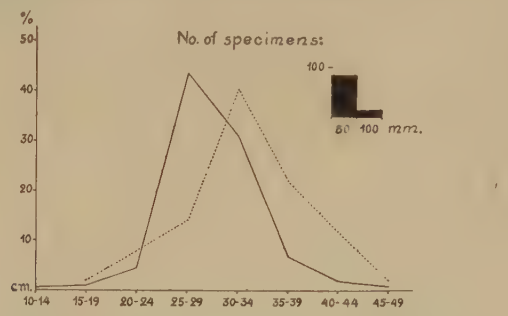

Fig. 3. The Percentage Length Distribution of Whiting from fishing experiments in the Skagerak, July 1947, with trawls of different mesh sizes.

Catches with cod-end meshes of 80 mm. ————.
— - — — - 100 mm. ·····.

The black columns give the number of whiting per 1 hour's trawling with 80 and 100 mm. cod-end meshes.

5.

Experimental Comparison of Fishing Capacities of Different Trawlers and Trawls.

By

A. R. Margetts

Introduction.

In order to establish the equivalent catching power of different fishing vessels two lines of study are being followed; one, which is being undertaken by a colleague, is by comparison of the landings from ships fishing on roughly the same grounds, and the other, with which this paper is concerned, is experimental, by direct comparison of the catches of different vessels fishing closely together. The aim is to find factors usable in assessing the total fishing power of fleets of fishing vessels variously constituted.

The results of some experiments are presented here. Besides comparing catching powers these experiments also throw light on both the actions of trawls and, indirectly, the behaviour of some fishes in relation to trawls.

I would like to record appreciation of the work at sea of all persons taking part in the experiments, particularly Dr. Tåning (M.V. "Dana"), Mr. B. B. Parrish (S. T. "Explorer"), Mr. L. K. Boerema (TX 14), and the skippers of the ships, whose comments on the interpretation of results have been most helpful.

Method of Experiments.

The general method of the experiments has been to treat a ship and its particular gear as a fishing unit, comprising a group of variables each of which have been noted, e. g., dimensions and power of the ship, size and shape of net, accessories fitted etc. The primary comparison made has been the overall one of the catches of fish in unit time by two such fishing units. Secondary comparisons to determine the component effect of any variable in a fishing unit have been made by integrating these experiments into a series, or by carrying out entirely separate controlled experiments using one ship and varying only one component of its gear.

In making the overall comparisons two ships, each using their usual gear with minor modifications to suit the particular ground chosen for the experiment and towing at their optimum speeds, have fished as closely together as was practicable on a fishing ground marked, whenever possible, by one or two dahn buoys. The cod-ends used by each ship in any one experiment have been of similar mesh size. Usually both ships have shot and hauled their gear simultaneously, the times for the beginning and end of a haul being noted at the "squaring up" and "knocking out" of the warps. Details of the fishing times, of all items of gear used, of cod-end mesh size as measured by internal flat gauge, of any damage sustained by the gear, and of the composition of catches from each haul were recorded. The catch from each haul was sorted and the total weight and number of each species measured and counted. Length measurements were made of samples of the predominant fish species. The quantity of invertebrates and shells was estimated and the predominant species of these were identified.

Results.

In presenting the results the figures for any hauls affected by damaged gear or faulty fishing have been rejected. Furthermore, no results have been taken as worth reporting here unless some consistency was shown in successive pairs of hauls. The inter-ship factors are expressed as direct ratios of the total catches of each species over a series of hauls made by one ship to the comparable total catches made by another ship. Some are based on rather few matched pairs of hauls or on small catches so that, as the effect of sampling errors on them may have been considerable, they require further substantiation.

Table 1. **Specification of Trawl Nets[1]).**

"Sir Lancelot" "Lowestoft" No. 4 Trawl.			
Upper Wings	85/16/32 ft.	152 mm. Mesh	
Lower Wings	200/50/30/66 ft.	127 mm. Mesh	
Square	250/200/30 ft.	152 mm. Mesh	
Belly and Batings	200/90/28 ft.	127 mm., 114 mm., 101 mm., and 89 mm. Mesh	
Headline	80 ft.		
Groundrope	116 ft. (2 × 48 ft. and bosom 20 ft.)		
Material	Untreated 112/3 ply sisal.		
Otter Boards	9 ft. 6 ins. × 4 ft. 8 ins. Heavily built.		
Legs	12 ft. Upper of combination wire, lower of heavy chain.		
Headline Floats	24 of $7^1/_2$ ins. diameter.		
"Platessa" "Lowestoft" No. 2 Trawl			
Upper Wings	70/12/$23^1/_2$ ft.	140 mm. Mesh	
Lower Wings	190/45/20/54 ft.	127 mm. Mesh	
Square	210/190/21 ft.	140 mm. Mesh	
Belly and Batings	190/80/32 ft.	127 mm., 114 mm., 101 mm., and 89 mm. Mesh.	
Headline	62 ft.		
Groundrope	88 ft. (2 × 36 ft. and bosom 16 ft.)		
Material	Untreated 125/3 ply sisal.		
Otter Boards	8 ft. 6 ins. × 4 ft. 6 ins. Heavily built.		
Legs	7 ft. Upper of rope, lower of heavy chain.		
Headline floats	9 of 8 ins. diameter.		
Dutch Cutter TX 14			
Upper Wings	80/30/50 ft.	90 mm. Mesh	Lengths calculated.
Lower Wings	240/85/30/59 ft.	90 mm. Mesh	
Square	270/240/9 ft.	90 mm. Mesh	
Belly and Batings	240/70/$47^1/_2$ ft.	90 mm. and 80 mm. Mesh	
Headline	98 ft.		
Groundrope	125 ft. (2 × 45 ft. and bosom 35 ft.).		
Material	1947, Flax. 1948, Hemp.		
Otter boards	8 ft. × 4 ft. Lightly built.		
Legs	1947, None. 1948, 11 ft. of rope.		
Headline floats	None.		
"Explorer" "Aberdeen" Trawl			
Upper Wings	72/9/43 ft.	140 mm. Mesh	
Lower Wings	200/50 /30/65 ft.	140 mm. Mesh	
Square	227/200/15 ft.	140 mm. Mesh	
Belly and Batings	200/100/27 ft.	127 mm., 101 mm., and 89 mm. Mesh	
Headline	112 ft.		
Groundrope	138 ft. (2 × 58 ft. and bosom 22 ft.)		
Material	Tarred 110/3 ply sisal.		
Otter boards	9 ft. 6 ins. × 4 ft. 3 ins.		
Legs	None.		
Headline floats	None.		
"Dana"			
Upper Wings	55/10/18 ft.	140 mm. Mesh	Lengths calculated
Lower Wings	180/40/20/40 ft.	140 mm. Mesh	
Square	180/180/$20^1/_2$ ft.	140 mm. Mesh	
Belly and Batings	180/90/24 ft.	120 mm. and 100 mm. Mesh	
Headline	52 ft.		
Groundrope	74 ft.		
Material	3 ply Manilla.		
Otter Boards	5 ft. 5 ins. × 2 ft. 6 ins.		
Headline Floats	3 of 2 litres.		
Legs	None.		

[1]) 85/16/32 ft. Means that the netting is braided from width 85 meshes down to width 16 meshes in length 32 ft.

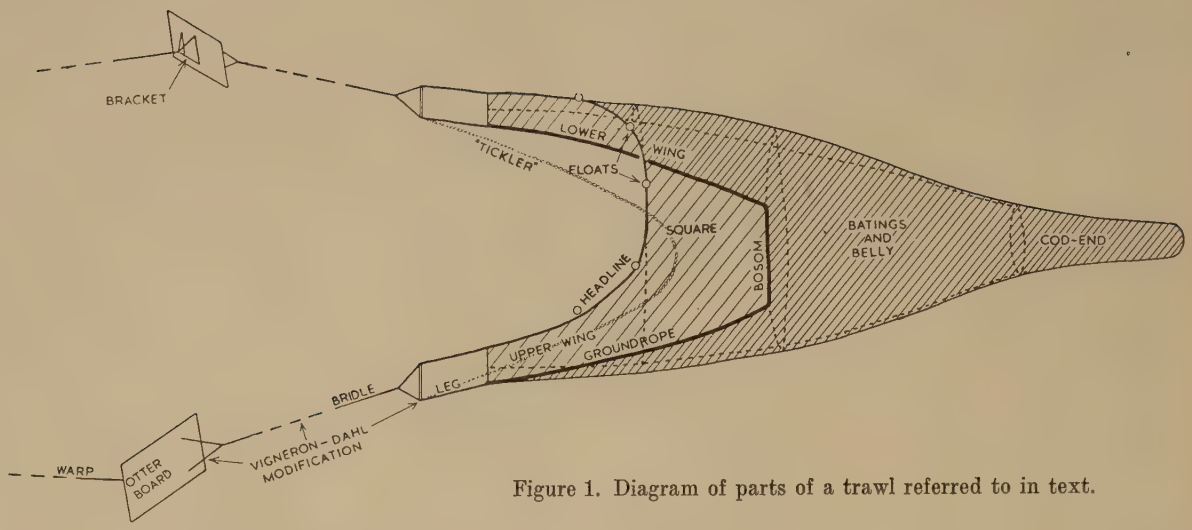

Figure 1. Diagram of parts of a trawl referred to in text.

Figure 1 illustrates the nomenclature of trawl parts referred to in the text. The plan diagrams in Figure 2, illustrating the important differences in the shapes of the particular trawls used in the experiments, are all to the same scale for lengths, but the widths are drawn to another scale employing the product of the number of meshes and their size. In Table 1 all mesh sizes are given as the circumference of the spool used in their manufacture.

Experiment 1. S.T. "Sir Lancelot" - M.T. "Platessa".

This experiment, which has been carried out twice, first in May 1947 and again in April 1948, compared trawlers of two different sizes with the larger trawler using a scaled-up version of the smaller trawler's gear. The two ships therefore worked with nets of the same shape and with similar accessory components.

"Sir Lancelot", a steam trawler of length 125 ft. between perpendiculars, and 296 tons gross, worked a "Lowestoft" No. 4 80 ft. headline otter trawl. Full specifications are given in Table 1. The groundrope, which was composed of wire wound with rope to a diameter of $3^1/_2$ inches and then loosely wound with chain, was attached to the net through a big and little bolsh. Wooden bosom bobbins of 12 inch and 8 inch diameter and a single "tickler" of $^1/_2$ inch chain between otter boards were fitted.

"Platessa", a motor trawler of length 90 ft. b. p., and 112 tons gross, driven by a motor of 240 b.h.p., worked a "Lowestoft" No. 2 62 ft. headline otter trawl. Specifications are given in Table 1. The groundrope and bosom were similar to those used by "Sir Lancelot". A single tickler of $^3/_8$ inch chain was fitted between otter boards.

It will be seen from Table 1 and Figure 2 that these trawls had relatively short wings and large squares, were heavily weighted, and were of such dimensions that the main towing strains were taken by the groundropes, allowing the headlines to be raised by their floats.

In both experiments the fishing grounds were marked with dahn buoys and a small area was fished for several days, 13 comparable pairs of hauls being made in 1947 and 16 in 1948. The two ships worked in their own time in 1947, not shooting and hauling simultaneously as they did in 1948.

From the length measurements (Tables 2 a and b) it is evident that the two ships were sampling the

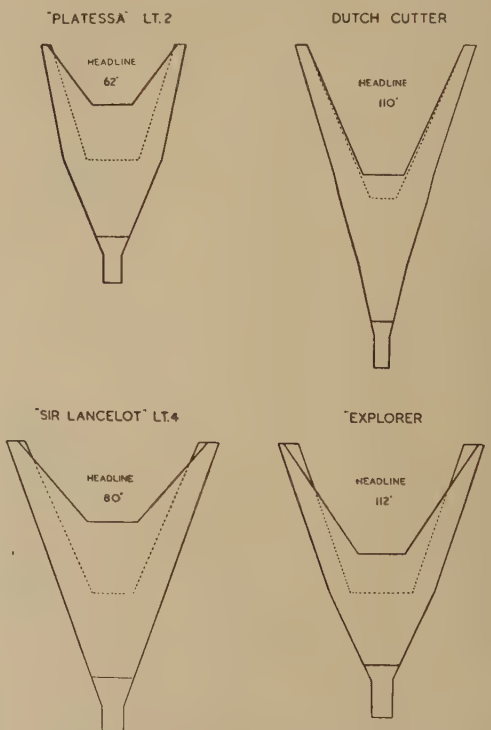

Figure 2. Plan-diagrams of trawl nets used by named vessels.

same populations of fish, so that direct comparisons of quantities of catches by weight and numbers are justified. There is reason to believe that a slight bias, working in opposite directions in the two experiments and affecting particularly the smaller figures, was introduced through the use of a faulty balance so that comparisons of numbers have been preferred to comparisons of weights.

The results from the two separate experiments (Tables 3 a and b) are illustrated in Figure 3. They are in satisfactorily close agreement except in the case of gurnards, the explanation of which lone discrepancy is not apparent. As might have been expected, the proportions of different species of fish in the catches of the two vessels were similar. The ratio between headline lengths, "Sir Lancelot": "Platessa", was 1·29:1, and of total maximum distances between otter boards (including legs) 1·37 : 1. These are almost the same as the ratios of catches, particularly of plaice which was the predominant species of fish caught.

Experiment 2. M.T. "Platessa" - Dutch Motor Cutter, TX 14.

This experiment also has been carried out twice, first in July 1947 and again in June 1948. The ships were somewhat similar but their gears differed considerably.

"Platessa" used the same gear as in Experiment 1 above, but with a soft bosom replacing the bobbins.

The Dutch motor cutter "Vier Gebroeders", registration number TX 14, of length about 75 ft., driven by a motor of 150 b.h.p. in 1947 and of 200 b.h.p. in 1948, worked a light otter trawl of 98 ft. headline in 1947 and 110 ft. headline in 1948. Full specifications are given in Table 1. The otter boards were of the same area but lighter than those used by "Platessa", and with the brackets set nearer to the lower than to the upper edge. In 1947 a very light groundrope wound loosely with small chain was used, but in 1948 the groundrope was replaced by $^1/_2$ inch chain attached directly to the lower wings and bosom. A tickler chain, between otter boards, was used at night in 1948 only.

The Dutch trawl was relatively lighter and larger than the "Lowestoft" trawl, with much longer wings, smaller square, and smaller meshes in parts other

Table 3 a. Catches by Steam Trawler "Sir Lancelot" and Motor Trawler "Platessa", May, 1947.

Species		Sir Lancelot	Platessa	Sir Lancelot/ Platessa per unit time
	Hours fishing:	33·4	35·0	
Plaice	Wt. in Lbs.	1,329	1,064	1·3
	Numbers	2,690	2,031	1·4
Sole	Wt. in Lbs.	142	110	1·3
Turbot & Brill	Wt. in Lbs.	729	623	1·2
Skate & Rays	Wt. in Lbs.	356	213	1·7
Dab	Wt. in Lbs.	267	195	1·4
Gurnards	Wt. in Lbs.	1,292	743	1·8

Table 2. Measurements of Plaice caught by Trawlers "Sir Lancelot" and "Platessa".

2 a.	May, 1947 Number		May, 1947 °/₀₀		April, 1948 Number		April, 1948 °/₀₀	2 b.
Length cm.	Sir L'lot	Platessa	Sir L'lot	Platessa	Sir L'lot	Platessa	Sir L'lot	Platessa
12					—	1	—	0
13					—	2	—	1
14					4	3	1	1
15					6	2	1	1
16					20	14	5	4
17					33	33	8	10
18					35	25	8	8
19	1	2	0	1	48	34	12	11
20	5	10	2	5	109	67	26	21
21	40	15	15	7	117	103	28	33
22	67	58	25	27	187	142	45	45
23	92	66	35	30	226	179	55	57
24	179	125	67	58	311	251	75	80
25	201	164	75	76	401	288	97	92
26	261	203	98	94	432	298	105	95
27	351	282	132	130	460	328	111	105
28	391	307	147	142	407	360	98	115
29	293	275	110	127	417	287	101	91
30	290	242	109	112	342	217	83	69
31	192	138	72	64	193	175	47	56
32	121	122	45	56	144	125	35	40
33	66	58	25	27	70	62	17	20
34	55	41	21	19	53	43	13	14
35	23	21	9	10	34	20	8	6
36	14	16	5	7	24	24	6	8
37	5	5	2	2	14	12	3	4
38	3	2	1	1	16	9	4	3
39	1	7	0	3	5	12	1	4
40	1	2	0	1	4	4	1	1
41	2	3	1	1	3	4	1	1
42	6	—	2	—	2	6	1	2
43	—	—	—	—	2	1	1	0
44	—	—	—	—	4	1	1	0
45	2	—	1	—	2	2	1	1
46	3		1	—	2	2	1	1
47	—	—		—	—	—		—
48	1	—	0	—	—	1	—	0
49	—	1		0	—	1	—	0
50	—				—	—		—
51	—				1	—	0	—
55	—				1	—	0	—
56	1		0					
57	—				1	—	0	
Total	2,667	2,165			4,130	3,138		

Table 3 b. Catches by "Sir Lancelot" and "Platessa", April, 1948.

Species	Numbers Caught		
	Sir Lancelot	Platessa	Sir Lancelot/ Platessa
Plaice	4,342	3,275	1·3
Sole	47	36	1·3
Whiting	139	95	1·5
Dab	2,199	2,108	1·0
Gurnard	2,195	3,753	0·6

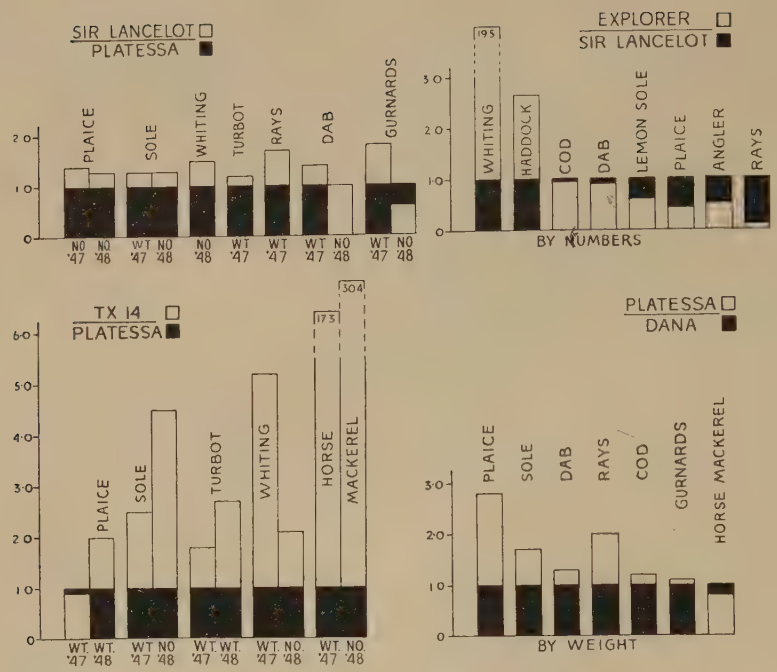

Figure 3. Ratios of catches of various species of fish by named vessels.

than the cod-end (Fig. 2). In operation its groundrope was slack and headline taut in contrast to the taut groundrope and slack headline of the "Lowestoft" trawl. It was claimed that the lower position of the otter board brackets kept the boards on the sea bed more efficiently. The ratios of headline lengths, TX 14: "Platessa", were 1·6 : 1 in 1947 and 1·8 : 1 in 1948, while those of total maximum distances between otter boards were 1·3 : 1 in 1947 and 1·6 : 1 in 1948.

The ships fished as closely together as possible, shooting and hauling simultaneously, without working to a dahn buoy. TX 14 towed slightly faster than "Platessa".

In the 1947 experiment 17 comparable pairs of hauls were made on two different grounds, the first with a sandy and the second with a muddy bottom. Twenty comparable pairs of hauls were made in 1948, working on a sandy ground.

In 1947 weights of all catches by TX 14 were estimated and later compensated by the factor, always approaching 1·0, relating the estimated and true weights (as given by the weights landed on the fish market) of marketable fish. In 1948 catches of marketable fish were weighed, but the total weights of undersized fish were roughly estimated. The results are given in Tables 4 a and b, and illustrated in Figure 3. They show TX 14 to have been more successful in fishing for all species of both flatfish and round fish, and also an increase in the ratios, TX 14 : "Platessa", between 1947 and 1948 consistent with the increase in size of the Dutch trawl. TX 14, with the larger trawl in 1948, caught twice as much plaice and more than four times as many soles as did "Platessa". The length distributions of the catches of plaice by the two ships were similar (Table 5). That the very high figure for the ratio of catches of horse mackerel has not been greatly affected by the uneven local distribution of this species is indicated by the similarity of results from the two experiments, by its occurrence in almost every haul, and by the fairly large number of hauls made.

In 1948 TX 14 collected an average of approximately six baskets of invertebrate "soil" per haul while "Platessa" collected about three-quarters of a basket per haul. This "soil" consisted mainly of starfish.

Experiment 3. S.T. "Sir Lancelot" - S.T. "Explorer".

This experiment is described in detail in the paper by Parrish (1) in this volume.

"Sir Lancelot" used the same net as in Experiment 1 above, but with the Vigneron-Dahl modification incorporating 30 fm. bridles and with a soft bosom replacing the bobbins. No tickler chain was used.

"Explorer", of length 138 ft. b.p., and 324 tons gross, worked an "Aberdeen" 112 ft. headline otter trawl. Specifications are given in Table 1. The groundropes and bosom were similar to those used by "Sir Lancelot". No tickler or legs were fitted.

It will be seen from Table 1 and Figure 2 that in the "Aberdeen" trawl the wings were longer, the square smaller, and some of the meshes slightly smaller than in the "Lowestoft" trawl, and also that

Table 4 a. Weight in Lbs. of Catches of Dutch Cutter TX 14 and English Trawler "Platessa", July, 1947.

Species	Series of Hauls A			Series of Hauls B			Total all Hauls		
	Platessa	TX 14[1])	TX 14 / Platessa	Platessa	TX 14[1])	TX 14 / Platessa	Platessa	TX 14[1])	TX 14 / Platessa
Plaice	1,255	1,194	0·95	1,950	1,664	0·85	3,205	2,858	0·9
Sole	214	386	1·8	175	597	3·4	389	983	2·5
Turbot	114	249	2·2	123	187	1·5	237	436	1·8
Whiting	40	208	5·2	53	278	5·2	93	486	5·2
Horse Mackerel ..	8	158	20	15	239	16	23	397	17·3

[1]) Estimated Weights. Series A: Cod-ends of Mesh Size 70–75 mm. Series B: Cod-ends of Mesh Size 50–60 mm.

Table 4 b. Catches by Dutch Cutter TX 14 and English Trawler "Platessa", June 1948.

Species	Units	Series of Hauls A			Series of Hauls B			Total, all Hauls		
		Platessa	TX 14	TX 14 / Platessa	Platessa	TX 14	TX 14 / Platessa	Platessa	TX 14	TX 14 / Platessa
Plaice	Wt. in Lbs.	1,211	2,929[1])	2·4	1,490	2,577[1])	1·7	2,701	5,506	2·0
Sole	Nos.	162	931	5·7	192	650	3·4	354	1,581	4·5
Turbot and Brill	Wt. in Lbs.	65	179	2·8	52	138	2·7	117	317	2·7
Whiting	Nos.	—	—	—	—	—	—	419	899[1])	2·1
Horse Mackerel...	Nos.	—	—	—	—	—	—	145	4,408	30·4

[1]) Figure includes estimated quantity of undersized fish. Series A: TX 14 using Tickler chain. Series B: TX 14 without Tickler chain.

the main towing strain was taken by the headline and upper part of the net. It more nearly resembled the Dutch cutter's trawl than the "Lowestoft" trawl.

The results given in Tables 6 and 7 and illustrated in Figure 3 are based on 7 comparable pairs of hauls and show marked differences in the species selectivities of these two trawls. "Explorer" caught more haddock and whiting but less of those fish living closer to the sea-bed, including plaice, skate, rays, anglers and other flatfish, than did "Sir Lancelot". Furthermore, there are differences in the size distributions of the haddock caught by these two ships (Tables 8 a and b), "Explorer" catching more haddock of length less than 42 cm. but fewer of length greater than 42 cm. than did "Sir Lancelot". These differences, although between small numbers, are probably significant. "Sir Lancelot" collected considerably more invertebrates (mostly shells, both full and empty, of *Modiola modiolus* with commensal anemones, *Echinus esculentus* and *Cancer pagurus*) than did "Explorer", and her net was damaged more often and more severely, being ripped seven times as against the "Aberdeen" net being ripped twice and coming fast on a boulder once. The possibility of damage to gear being due to faulty rigging or peculiarities of the way in which the ship fished must not be excluded, but the facts that rocks were caught and that the species of invertebrates found were those commonly frequenting rough ground indicate that the nature of the bottom was at least the main cause of damage to gear.

Experiment 4. M.T. "Platessa" - M.T. "Dana".

This experiment was anomalous on account of "Dana" fishing with gear which was in no way typical of that class of vessel.

"Platessa" used the same gear as in Experiment 1 above.

Table 5. Measurements of Plaice caught by Dutch Cutter TX 14 and English Trawler "Platessa", June, 1948.

Length, cm.	‰ Platessa	‰ TX 14	Length, cm.	‰ Platessa	‰ TX 14
12	3	3	31	10	10
13	3	5	32	9	9
14	7	13	33	4	3
15	14	14	34	3	5
16	13	29	35	3	4
17	24	23	36	2	5
18	28	28	37	1	2
19	48	31	38	4	1
20	67	70	39	1	1
21	101	108	40	2	0
22	126	117	41	1	2
23	126	119	42	1	—
24	119	121	43	1	1
25	92	98	44	1	1
26	72	66	45	—	1
27	44	47	46	0	1
28	26	29	47	0	1
29	24	20	51	1	—
30	19	12			

Table 6. Percentage Weight Composition of Catches by Trawlers "Sir Lancelot" and "Explorer", December, 1947.

Species	% of Total Catch		% of Total Catch less Cod and "Mixed"	
	Explorer	Sir Lancelot	Explorer	Sir Lancelot
Haddock.....	59	35	68	44
Cod	10	14	—	—
Whiting.....	14	1	16	1
Skate & Rays.	2	19	2	23
Angler.....	7	16	9	20
"Flats"	5	10	5	12
"Mixed"	3	5	—	—

"Dana" a large trawler of length 161 ft. b.p., used a 50 ft. headline otter trawl fitted with a bosom tickler and three headline floats, but without bobbins or legs. This gear was towed on a single warp with bridles to the otter boards. Specifications of the net are given in Table 1.

Three pairs of hauls were made on one ground which supported a population apparently almost exclusively of rays, followed by 13 pairs of hauls on another ground yielding chiefly plaice.

Table 9 and Figure 3 compare the catches of fish by these two vessels and show that "Platessa" caught considerably more of all species except horse mackerel. The figures for this species are liable to error on account of its very localised distribution which resulted in its being taken in only some of the hauls. The length distributions of plaice caught by the two ships were closely similar.

Discussion and Conclusions.

The true explanation of differences in the catches of the various fishing units may not be those which, on present information, appear most likely. The drawing of provisional conclusions will, however, serve to summarize the facts so far ascertained, and further work can be directed to confirmation of points that appear to be of greatest interest. In particular a possibility which has to be borne in mind in this work is that the gear may not have been fishing at optimum efficiency. For instance, in one experiment it was found that a relatively small change in the weight of the legs and ground-rope affected the quantity of catches considerably. Such a fault would give rise to misleading results.

Some features of the results are common to more than one experiment and these are discussed below.

Table 7. Catches by Trawlers "Sir Lancelot" and "Explorer", December, 1947.

Species		Weight in Lbs.			Numbers		
		Explorer	Sir Lancelot	Explorer / Sir Lancelot	Explorer	Sir Lancelot	Explorer / Sir Lancelot
Haddock.....		1,360	692	1·97	1,447	547	2·65
Cod		235	273	0·86	75	78	0·96
Whiting		320	20[1])	16·0	547	28	19·5
Skate and Rays.....		40	377	0·11	19	232	0·08
Angler.....		172	325	0·53	48	97	0·49
Plaice	Flatfish.....	112	196	0·57	24	56	0·43
Lemon Sole.....					23	38	0·6
Dab.....					78	88	0·89
Long Rough Dab					76	35	—
Megrim.....					0	1	—
Witch					0	5	—
Turbot					2	1	—
Brill.....					0	1	—
Grey Gurnard...	Mixed	66	100	0·66	59	67	—
Dogfish					8	5	—
Catfish.....					2	2	—
Coalfish.....					0	2	—
Ling.....					2	2	—
Hake.....					2	3	—
Latchet.....					0	3	—
Tope					0	1	—
Horse Mackerel..					2	0	—
Mackerel.....					1	0	—
Total.....		2,305	1,983	1·16	—	—	—
Total less mixed.....		2,239	1,883	1·19	—	—	—
Total less mixed and Cod.....		2,004	1,610	1·24	—	—	—

[1]) Estimated figure.

On the Behaviour of Trawls.

From Experiment 1, in which trawls of the same shape but of different sizes were used, it appears that the composition of the catches is independent of size of the trawl but that the quantity of the catches of flatfish is, as far as can be decided by testing only two sizes of trawl, almost directly proportional to the size of the trawl as measured by the length of the headline. The width of the mouth, or "spread", of the net when fishing will be directly proportional to the headline lengths of trawls of similar shape. The spread of the net cannot be greater than the headline length, while the working distance between otter boards, or spread of the trawl, will be proportional to the total length of headline, legs and bridles. When fishing, the spread of the trawl in relation to the maximum distance between otter boards, will be dependent upon the efficiency of the otter boards, the speed of towing, the weight of the groundrope, whether ticklers and headline floats are fitted, and the resistance of the net, which will itself be dependent upon the size of its meshes, the material used in manufacture, and the shape of the net. Experiments are in hand to determine the relation between the spread and dimensions of a trawl.

Preliminary results indicate that the spread of the "Lowestoft" No. 2 trawl used by "Platessa", rigged as in Experiment 1, is about 70% of the total maximum distance between otter boards. The area of "gape" of the net will depend upon its spread and the height of the headline above the groundrope, which will vary with the design of the trawl and the fitting of headline floats.

The spread of the Dutch cutter's trawl in the 1948 experiment was probably twice that of "Platessa"'s trawl since the net and fittings were much lighter in all parts, the headline and legs were longer, the doors of about the same size, and the cutter's towing speed slightly faster. When fishing, the cutter's trawl headline was kept taut while the groundline remained slack. The towing strain was taken along the groundrope of the "Lowestoft" trawl, leaving the headline slack to be raised by the floats. The Dutch cutter covered probably rather more than twice as large an area of ground per haul as did "Platessa". The ratio of the spread of "Dana"'s net to the spread of "Platessa"'s was probably less than the ratio of headline lengths as the "Dana"'s trawl was towed on a single warp with two bridles to the otter boards.

Table 8 a. Measurements of Haddock caught by Trawlers "Sir Lancelot" and "Explorer", December, 1947.

Length, cm.	Actual Number		‰	
	Explorer	Sir Lancelot	Explorer	Sir Lancelot
24	1	—	1	—
25	1	—	1	—
26	3	2	2	4
27	6	1	4	2
28	12	8	8	15
29	41	16	28	29
30	58	23	40	42
31	142	48	98	88
32	188	47	130	86
33	209	45	145	82
34	194	46	134	84
35	160	50	111	91
36	109	23	75	42
37	65	27	45	49
38	45	19	31	35
39	35	19	24	35
40	18	6	12	11
41	36	17	25	31
42	22	20	15	37
43	24	23	17	42
44	15	16	10	29
45	7	10	5	18
46	9	19	6	35
47	6	9	4	16
48	9	14	6	26
49	8	5	6	9
50	7	6	5	11
51	2	6	1	11
52	4	5	3	9
53	3	6	2	11
54	3	2	2	4
55	2	3	1	5
56	1	3	1	5
57	—	2	—	4
58	1	—	1	—
59	1	—	1	—
60	—	1	—	2
Total ...	1,447	547		

Table 8 b. Quantities of large Haddock in Catches by Trawlers "Sir Lancelot" and "Explorer", December, 1947.

Length greater than	Number		
	Explorer	Sir Lancelot	Explorer/ Sir Lancelot
40 cm.	178	173	1·03
45 cm.	63	91	0·69
50 cm.	24	34	0·71

Table 9. Catches by Trawlers "Platessa" and "Dana", August, 1947.

Species		Weight Ratios Platessa/Dana	
		Ground A	Ground B
Plaice	"Flatfish"	1·2[1])	2·8
Dab			1·3
Sole			1·7
Skate and Rays		2·0	4·8[1])
Dogfish		3·8[1])	1·2
Cod	"Mixed"	0·7[1])	1·2
Horse Mackerel			0·8
Gurnards			1·1
"Mixed"			0·5[1])

[1]) Comparisons of Small Catches.

The catches of plaice by TX 14, "Sir Lancelot", "Platessa" and "Dana" were in that order, with TX 14 highest and "Dana" lowest. The headline lengths and the presumed spreads of their trawls, as closely as they can be estimated, were in the same order. That the spread of the net alone is not as important as the total spread between otter boards for obtaining greatest catches of plaice is indicated by the facts that the ratio of catches of plaice, "Platessa" : "Dana", was as high as 2·8 : 1, whereas the headlines were only in the ratio of 1·2 : 1. Also, after making allowance for the increased net size in 1948, it is apparent that TX 14 caught relatively more when fitted with legs, and "Sir Lancelot" with Vigneron-Dahl gear caught more plaice than did "Explorer" without that gear although the spreads of the "Explorer"s net was the wider. (However, the difference in catches of flatfish by these two vessels was greater than might be accounted for solely by the increased efficiency of the gear due to the Vigneron-Dahl modification.)

The use of a tickler chain probably reduces the spread between the otter boards, but certainly appears to increase the catches of flatfish. Its effect may depend on other features of the gear with which it is being used and, very probably, with both the character of the sea-bottom and the condition or activity of the fish, e. g., it is estimated that when a tickler was fitted to the Dutch cutter's trawl at night, catches of plaice were increased by about 18% while those of soles were increased by 57%.

The flexibility and small diameter of the Dutch cutter's groundline in 1948 which would, it is supposed, keep very close to the sea-bed, together with features of the behaviour of fish in relation to fishing gear, was probably responsible for the greater efficiency of the cutter's gear in catching soles and also for the much larger catches of invertebrates taken by that vessel as compared with "Platessa". Similarly, in Experiment 3 above, the greater catches by the "Lowestoft" trawl, as compared with the "Aberdeen" trawl, of bottom living invertebrates and of such species of fish as plaice, anglers, and rays, together with the more severe and frequent damage sustained by the "Lowestoft" net, may be accounted for by assuming that the "Lowestoft" trawl with Vigneron-Dahl modifications, designed primarily for catching flatfish, was fishing closer to the bottom than was the "Aberdeen" trawl which was designed primarily for catching roundfish. This experiment shows the way in which these nets were fishing on the bottom clear of any complications from the use of tickler chains.

The action of legs and Vigneron-Dahl bridles is presumably rather like that of seine net warps, driving fish towards the ground to be swept by the net. The use of legs by the Dutch cutter in 1948 and not in 1947 can be held to account for some, at least, of the difference in results obtained in these two years, between which the comparative efficiency of the Dutch cutter in catching flatfish was apparently almost doubled. It may well be that the use of Vigneron-Dahl gear by "Sir Lancelot" in the experiment with "Explorer" was responsible for the former ship catching more of the larger haddock, and also that the relatively poor catches made by "Dana" were to some extent due to towing the trawl on a single warp with two bridles which might tend to reduce the spread and drive fish away from the edge of the area of ground to be swept by the net.

Some of the results obtained indicate that parts of the net other than the cod-end may perhaps exercise considerable selection of the fish caught, not only by virtue of the size of their meshes, but also by the fishing shape of these meshes. Todd (2), in covered net experiments, found that some haddock and whiting escaped through the batings and square of a beam trawl. His results were probably underestimates, as some of the fish passing through the batings and square to be stopped by the cover netting would probably have found their way back into the trawl to be retained by the cod-end. From the net specifications (Table 1), it will be seen that, after allowing for some slack to be taken up on attachment to the headline, the upper netting of the "Lowestoft" trawls will be slack when the net is towed, while that of the "Aberdeen" and Dutch cutter's trawls will be taut with the square almost parallel to the sea bottom. It might therefore be expected that, as the strain would be acting lengthwise, the meshes in these parts of the latter trawls would be more rigid and narrower than those of the "Lowestoft" trawl. The angle at which a fish meets with netting will probably affect its selectivity, and this is likely to be different in the upper parts of these two trawls. Such differences may account for some of the difference between the catches of small haddock and whiting by the "Lowestoft" and both the "Aberdeen" and Dutch trawls. They seem particularly likely to account for the failure of the "Lowestoft" trawl to catch more than a few horsemackerel.

On the Behaviour of Fish towards Trawls.

The way in which different species of fish behave when disturbed by fishing gear will affect the catches made by different types of gear fishing a particular mixed local population of fish at the same time. The different effects on catches of plaice and soles of the use of a tickler chain by the Dutch cutter, and the fact that a seine net can outfish a trawl on plaice but not on soles (3), are probably attributable to differences in reactions of these fish to the gear under certain conditions. It is also conceivable that the greater catches of large haddock by the "Lowestoft" trawl with Vigneron-Dahl modifications, as compared with the "Aberdeen" trawl, were due to differences in the behaviour of different sizes of haddock in relation to the action of the bridles. as well as to the mesh effect discussed above.

If horse-mackerel dart slightly upward when disturbed they would pass more easily through the larger open meshes in the upper part of the "Lowestoft" trawl.

Results in Relation to Fishery Statistics.

From these few experiments there are indications that a comparison of regional densities of one species of fish by means of the index of catch per time fishing can be misleading on account of the apparent differences between species selectivities of trawls typical of those used in different regions. For instance, if the "Aberdeen" type of trawl which is widely used in the northern North Sea was replaced by the "Lowestoft" type of trawl it is probable that the densitites of different species, as calculated from market statistics, would apparently alter because the "Lowestoft" trawl seems to catch relatively more of the flatfish and less of the roundfish than does the "Aberdeen" trawl.

Summary of Conclusions.

(1) Evaluation of the effects on catches of particular components in trawl gear appears to be practicable using comparative trials such as those described. For example, there is reason to believe that, other things being equal, the catches of plaice are directly proportional to the distances between otter boards.

(2) Effects are not the same for all species of fish; but these experiments suggest that a lighter long-winged trawl with headline taut and groundrope slack can be used to catch most species of fish more effectively and more economically than can heavier gear.

(3) The demonstrated differences between species selectivities of different trawls may prove useful in the interpretation of statistics concerning densities of certain fish species in different regions.

References.

(1) Parrish, B. B. "Fishing Capacities of Gears used by English and Scottish Research Vessels". This volume, p. 91.

(2) Todd, R. A. "Covered net experiments". North Sea Fisheries Investigation Committee. Third Report on Fishery and Hydrographical Investigations, 1906—1908.

(3) Margetts, A. R. "Experimental Comparison of Fishing Capacities of Danish-Seiners and Trawlers". This volume, p. 82.

6.

Experimental Comparison of Fishing Capacities of Danish-Seiners and Trawlers.

By

A. R. Margetts

Introduction.

The fishing capacities of a Danish-seiner and trawlers have been compared in two experiments of a series designed to find the equivalent fishing powers of various types of vessels using different gears. In the first of these two experiments the trawler "Platessa" worked with the seiner "Primula", and in the second the trawlers "Platessa" and "Sir Lancelot" worked with the seiner "Arabis". The results of the second are the more satisfactory and reliable, but both experiments are reported here.

I wish to thank the owners of M.V. "Arabis", Harry Franklin Ltd., Grimsby, and the skipper Mr. R. Cowie, together with Mr. J. F. Hansen, the skipper-owner of M. V. "Primula", for their invaluable co-operation in these experiments.

Method.

This description of the method will be concerned chiefly with the experiment involving "Arabis", "Platessa" and "Sir Lancelot", the other experiment with "Primula" and "Platessa" having been conducted along similar lines.

Seiners work by daylight only, whereas trawlers work throughout the day and night. It was therefore necessary to design the experiment with the object of comparing the total catches per 24 hours spent on the fishing ground by each vessel.

On a fishing ground chosen by the skipper of "Arabis", the seiner fished from an anchorage, while the trawlers fished immediately outside the limits of the area which could be swept by the seine from any one anchorage. Both types of vessel worked to their own time, the seiner making as many hauls in one day as the hours of daylight would allow, and the trawlers working by both day and night, shooting and hauling simultaneously, and making hauls of about 3 hours duration. The cod-ends used by all ships were as nearly as possible of the same mesh size.

Similar observations were made on all ships. Full details of the gear used and the timing of operations were recorded. Any damage to the gear was noted, as was any faulty fishing which might have affected the results. The catch from each haul was sorted, the number of each species of fish counted, and the total weight of plaice measured or estimated. Length measurements were made of the principal species caught, which in the experiment with "Arabis" were plaice and dabs, and in that with "Primula", plaice, dabs and haddock. The quantity of invertebrates was estimated and the predominant species identified. In order to compare the condition of the fish caught by the different methods of fishing, the number of plaice bruised on the underside of the head was counted and has been expressed as a percentage of the total number caught.

The Ships and their Gear.

The specifications of the gear used by each ship are given in Table 1.

"Sir Lancelot", a steam trawler of length 125 ft. b. p., and of a class normally manned by a crew of twelve, used an 80 ft. headline "Lowestoft" No. 4 otter trawl with the Vigneron-Dahl modification incorporating 30 fm. bridles.

"Platessa", a trawler of length 90 ft. b. p., driven by a 240 b.h.p. motor, is of a class normally manned by a crew of ten. Her trawl was a "Lowestoft" No. 2 with 62 ft. headline, of similar shape to, but smaller than that used by "Sir Lancelot". It was not fitted with Vigeron-Dahl gear.

"Arabis", of length 68 ft. b.p., and driven by a 160 b.h.p. motor, was manned by a crew of four. The net used was a Plaice seine, of headline length 27 fms., with warps of length 1100 fms. Two cod-ends

Table 1. **Specification of Gears[1]).**

"Sir Lancelot", "Lowestoft" No. 4 Trawl.

Upper Wings	85/16/32 ft.	6″ Mesh
Lower Wings	200/50/30/66 ft.	5″ Mesh
Square	250/200/30 ft.	6″ Mesh
Belly and Batings	200/90/28 ft.	5″, 4½″, 4″, 3½″ Mesh.
Cod-end	21 ft.	100 mm. Mesh
Material	Untreated. 112/3 ply sisal.	
Headline	80 ft.	
Groundrope	116 ft. (2 × 48 ft. and bosom 20 ft.) Bosom bobbins.	
Otter Boards	9 ft. 6 ins. × 4 ft. 8 ins. Heavily built.	
Legs	12 ft. of wire.	
Headline Floats	24 of 7½ ins. diameter.	
Vigneron-Dahl Bridles	30 fms.	
Tickler	½″ between Dan Lenos.	

"Platessa", "Lowestoft" No. 2 Trawl.

Upper Wings	70/12/23½ ft.	5½″ Mesh.
Lower Wings	190/45/20/54 ft.	5″ Mesh.
Square	210/190/21 ft.	5½″ Mesh.
Belly and Batings	190/80/32 ft.	5″, 4½″, 4″, 3½″ Mesh.
Cod-end	18 ft.	97 mm. Mesh
Material	Untreated 125/3 ply sisal.	
Headline	62 ft.	
Groundrope	88 ft. (2 × 36 ft. and bosom 16 ft.) Bosom bobbins.	
Otter Boards	8 ft. 6 ins. × 4 ft. 6 ins. Heavily built.	
Legs	7 ft. Upper of rope, lower of heavy chain.	
Headline Floats	9 of 8 ins. diameter.	
Vigneron-Dahl Gear	None.	
Tickler	⅜″ between otter boards.	

"Arabis", Franklin's No. 13 Plaice seine.

Headline	27 fms.	1¼″ Cotton rope.
Groundrope	27 fms.	1¼″ Cotton Rope.
Wings	13 fms.	5¼″ Mesh.
Bag	7 fms.	4½″ Mesh.
Cod-end	12 ft. 97 or 105 mm. Mesh.	
Material	Cotton.	
Warps	Each 1100 fm. 2½″ sisal rope.	
Headline Floats	13 of 5¼″ diameter.	
Groundrope Weights	40 lbs. of leads. 2 ft. of ⅜″ chain in each wing. 5 lbs. of 2″ Bass rope in bosom.	
Tickler	Bosom ⅜″.	

[1]) 85/16/32 ft. Means that the netting is braided from width 85 meshes down to width 16 meshes in length 32 ft.

of slightly different mesh sizes were used in the course of the experiment. The gear was shot in such a way that the distance covered in towing the warp-end back to the anchor was always short.

"Primula", of length 75 ft., driven by a 160 b.h.p. motor, and manned by a crew of five, used both a Plaice seine and an Intermediate Plaice seine with 1200 fms. warps.

Results.

The experiment with the seiner "Arabis" was carried out at the end of August when the length of daylight was such that the seiner was able to make more hauls per day than it could have done on the average day of the year (Table 2). To compensate for this when comparing the overall catching power of the

Table 2. **Fishing Time per Day of Seiner and Trawlers.**

Ship	Hours Sunlight		Time required for one haul, shooting fishing and hauling	No. of hauls per 24 hours	
	August, 28th	Equinox		August, 28th	Equinox
Seiner "Arabis"	13 hr. 51 mns.	12 hrs.	1 hr. 50 mns.	8	7
Trawler without V.D. Gear "Platessa"	—	—	3 hr. 20 mns.	7·2	7·2
Trawler with V.D. Gear "Sir Lancelot"	—	—	3 hr. 30 mns.	6·9	6·9

Table 3. Comparison of Quantities of Fish Caught by Seiner and Trawlers.

Species	Ship	No. of hauls	Total Quantity caught		Quantity/24 hours Aug. 28th		Ratios of Catches /24 hrs. Aug. 28th		Quantity/24 hours Equinox		Ratios of Catches /24 hrs. Equinox	
			Weight in lbs.	No.	Weight in lbs.	No.	Weight	No.	Weight in lbs.	No.	Weight	No.
Plaice	"Arabis"	29	5013	4587	1383	1265	4·4	3·2	1210	1107	3·9	2·8
	"Sir Lancelot"	20	1721	1940	594	669	1·9	1·7	594	669	1·9	1·7
	"Platessa"	20	873	1084	314	390	1·0	1·0	314	390	1·0	1·0
Dabs	"Arabis"	26	—	2421	—	745	—	0·7	—	652	—	0·6
	"Platessa"	20	—	2822	—	1016	—	1·0	—	1016	—	1·0
Soles	"Arabis"	29	—	10	—	3	—	0·1	—	2	—	0·0
	"Sir Lancelot"	20	—	192	—	66	—	1·4	—	66	—	1·4
	"Platessa"	20	—	130	—	47	—	1·0	—	47	—	1·0
Turbot and Brill	"Arabis"	29	—	14	—	4	—	0·7	—	3	—	0·5
	"Sir Lancelot"	20	—	31	—	11	—	1·8	—	11	—	1·8
	"Platessa"	20	—	18	—	6	—	1·0	—	6	—	1·0
Angler	"Arabis"	29	—	39	—	11	—	0·5	—	9	—	0·4
	"Sir Lancelot"	20	—	51	—	18	—	0·9	—	18	—	0·9
	"Platessa"	20	—	58	—	21	—	1·0	—	21	—	1·0
Gurnard	"Arabis"	29	—	1854	—	511	—	5·7	—	448	—	5·0
	"Sir Lancelot"	20	—	570	—	197	—	2·2	—	197	—	2·2
	"Platessa"	20	—	249	—	90	—	1·0	—	90	—	1·0

seiner with that of the trawlers, the equinox has been taken as the average day of the year, and the catches which the seiner might have been expected to make per 24 hours at the time of the equinox, had the experiment been carried out then, have been calculated. The choice of this day does not necessarily provide the best all-the-year round-factor for the efficiency of a seiner compared with that of a trawler, because seining is more restricted by winter weather than is trawling.

The data from any haul affected by damaged gear or faulty fishing, have been rejected.

The results in Table 3 are expressed as the quantities of fish caught by each vessel during the maximum successful fishing time in 24 hours spent on the fishing ground, both at the date of the experiment and at the date of the equinox. The ratios between the quantities caught by each vessel have been calculated. These apply under conditions entirely favourable to seining; they will be somewhat higher than the average figures over the entire year because, in their calculation, the effect of winter weather has not been considered.

In making thirty-five hauls, "Arabis" worked from seven different anchorages all of which lay within a rectangular area of about six square miles. Of these hauls twenty-nine have been used in calculating the results. The trawlers each made twenty-five hauls, of which twenty, including ten by day and ten by night, are considered here.

The most outstanding features of the quantitative results are that the seiner outfished the trawlers on plaice, but that the trawlers outfished the seiner on soles and other commercially important flatfish. The seiner caught about 180% more plaice than the smaller trawler and 60% more than the larger trawler. The trawlers caught more soles at night than they did in the daytime, but even so, the seiner was outfished on this species in daylight. The trawlers' catches of plaice did not vary with daylight and darkness. Only a few roundfish were caught by any vessel.

In the experiment with the seiner "Primula", two

Table 4. Comparison of Quantities of Fish Caught by Seiner and Trawlers.

Ground	Ship	No. of hauls Oct. 1st	No. of hauls per 24 hrs. at Equinox	Plaice			Haddock		
				Total catch (in st.) Oct. 1st	Catch per 24 hours at Equinox	Ratio $\frac{\text{seine}}{\text{trawl}}$ at Equinox	Total catch (in st.) Oct. 1st	Catch per 24 hours at Equinox	Ratio $\frac{\text{seine}}{\text{trawl}}$ at Equinox
A	"Primula" with Plaice seine	5	7	72	101	2·5	—	—	—
	"Platessa" with Tickler and Groundrope chains	3	7·2	17	41		—	—	
B	"Primula" with intermediate Plaice seine	6	6	139	139	8·0	184	184	1·8
	"Platessa" without Tickler and chains	3	7·2	7	17		42	101	

Table 5 a. Measurements of Dabs caught by Seiner "Arabis" and Trawlers "Sir Lancelot" and "Platessa", 1948.

Length Cm.	"Arabis"		"Sir Lancelot"					"Platessa"				
	Number (14 hauls)	‰	Number (3 hauls)	‰	Number raised to Arabis' fish. time	Ratio Arabis: Sir Lancelot	Smoothed Ratio	Number (20 hauls)	‰	Number raised to Arabis' fish. time	Ratio Arabis: Platessa	Smoothed Ratio
10	—	—	1	1	5	0	—	1	0	1	0	—
11	—	—	3	2	14	0	0·02	4	2	3	0	0·06
12	1	1	3	2	14	0·07	0·09	8	3	6	0·17	0·09
13	1	1	1	1	5	0·20	0·10	15	5	11	0·09	0·10
14	1	1	9	7	41	0·02	0·08	34	12	24	0·04	0·06
15	1	1	8	6	37	0·03	0·04	26	9	19	0·05	0·06
16	5	5	19	14	87	0·06	0·03	72	26	52	0·10	0·06
17	2	2	39	28	179	0·01	0·04	77	27	55	0·04	0·08
18	13	14	60	43	276	0·05	0·04	168	60	121	0·11	0·10
19	26	27	91	66	419	0·06	0·05	233	83	168	0·15	0·15
20	35	36	153	111	704	0·05	0·05	264	94	190	0·18	0·15
21	28	29	176	128	810	0·03	0·04	299	106	215	0·13	0·18
22	49	51	199	144	915	0·05	0·06	307	109	221	0·22	0·21
23	75	78	176	128	810	0·09	0·09	368	130	265	0·28	0 32
24	105	109	174	126	800	0·13	0·14	311	110	224	0·47	0·46
25	130	135	132	96	607	0·21	0·29	280	99	202	0·64	0·87
26	162	168	66	48	304	0·53	0·53	152	54	109	1·49	1·55
27	138	143	35	25	161	0·86	0·84	77	27	55	2·51	2·08
28	72	75	14	10	64	1·12	1·06	44	16	32	2·25	2·38
29	38	39	7	5	32	1·19	1·37	22	8	16	2·38	2·30
30	25	26	3	2	14	1·79	2·19	15	5	11	2·27	3·05
31	18	19	1	1	5	3·60	2·17	6	2	4	4·50	3·09
32	10	10	2	1	9	1·11	—	6	2	4	2·50	3·22
33	8	8	—	—	—	—	—	4	1	3	2·67	2·83
34	10	10	1	1	5	2·00	—	4	1	3	3·33	2·28
35	5	5	1	1	5	1·00	1·19	8	3	6	0·83	1·66
36	5	5	2	1	9	0·56	—	9	3	6	0·83	0·55
37	—	—	—	—	—	—	—	4	1	3	0	0·28
38	—	—	2	1	9	0	—	4	2	3	0	—
39	—	—	—	—	—	—	—	—	—			—
40	1	1	—	—	—	—	—	—	—	—	—	—
41	1	1	1	1	5	0·20	—	—	—	—	—	—
Total...	965		1,379		6,345			2,822		2,032		

grounds were fished, the second of which (ground B in Table 4) was not altogether suitable for trawling with the heavy "Lowestoft" gear on account of the presence of large quantities of sponge. The results are given in Table 4. They are based on very few hauls and upon estimated weights, but they confirm the finding of the experiment with "Arabis" that seining is superior to trawling for plaice, and they also provide data for haddock. "Primula", using an Intermediate Plaice seine, caught almost twice as much haddock as the trawler.

A comparison of the length distributions of seine-caught fish with those of trawl-caught fish shows similarities and differences of considerable interest. The present data are not complete enough for definite conclusions to be drawn on some points concerning the behaviour of the gear and fish, but indicate that a size selection of fish is exercised by the seining gear as a whole, apart from mesh selection within the net.

In both the experiment with "Arabis" and that with "Primula" the seines caught relatively less of the smaller and more of the larger dabs than did the trawls (Tables 5 (a) and (c), Figure 1 (a)). The modes of the trawlers' curves are at about 22 cm. while that of the seiners is at 26 cm. When the ratios of the numbers at each length caught by the seine to those caught by the trawl in the same fishing time are plotted against length (Figure 2 (a) Table 5 (a)) it is apparent that the seine was missing most of the dabs of length less than about 27 cm. The curve superficially resembles a mesh selection ogive. The numbers above 29 cm. are small.

The length distributions of seine- and trawl-caught plaice, on first inspection, appear rather similar to each other. But the size range of plaice on the ground was such that there were only very few of length less than 25 cm. The difference between the seiner's and trawlers' curves in Figure 1 (b) over the size range 20—27 cm. is nevertheless noteworthy. On plotting the ratios of numbers at each centimetre

Table 5 b. Measurements of Plaice caught by Seiner "Arabis" and Trawlers "Sir Lancelot" and "Platessa", 1948.

Length Cm.	"Arabis"		"Sir Lancelot"					"Platessa"				
	Number (18 hauls)	‰	Number (20 hauls)	‰	Number raised to Arabis' fish. time	Ratio Arabis: Sir Lancelot	Smoothed Ratio	Number (20 hauls)	‰	Number raised to Arabis' fish. time	Ratio Arabis: Platessa	Smoothed Ratio
18	—	—	1	1	1	0	—	—	—	—	—	—
19	1	0	1	1	1	1·00	0·33	2	2	2	0·50	—
20	—	—	9	5	8	0	0·37	4	4	4	0	0·20
21	1	0	9	5	8	0·12	0·14	10	9	9	0·11	0·13
22	4	2	15	8	13	0·31	0·23	16	15	15	0·27	0·30
23	8	3	35	18	31	0·26	0·32	16	15	15	0·53	0·49
24	16	7	46	24	41	0·39	0·43	26	24	24	0·67	0·73
25	32	13	56	29	50	0·64	0·66	35	32	32	1·00	1·00
26	65	27	77	40	68	0·96	0·91	53	49	49	1·33	1·35
27	118	49	117	60	104	1·13	1·13	74	68	69	1·71	1·54
28	169	70	148	76	131	1·29	1·24	114	105	106	1·59	1·92
29	205	85	179	92	159	1·29	1·27	90	83	83	2·47	2·02
30	195	81	179	92	159	1·23	1·36	105	97	97	2·01	2·33
31	204	84	146	75	130	1·57	1·40	88	81	81	2·52	2·33
32	162	67	131	67	116	1·40	1·53	71	65	66	2·45	2·47
33	156	64	109	56	97	1·61	1·70	69	64	64	2·44	2·55
34	132	55	71	37	63	2·10	1·88	52	48	48	2·75	2·89
35	115	48	68	35	60	1·92	2·01	36	33	33	3·48	3·40
36	123	51	69	35	61	2·02	1·97	33	30	31	3·97	3·43
37	85	35	48	25	43	1·98	1·81	32	29	30	2·83	3·64
38	62	26	49	25	43	1·44	1·62	16	15	15	4·13	3·46
39	58	24	45	23	40	1·45	1·56	18	17	17	3·41	4·11
40	48	20	30	15	27	1·78	1·60	11	10	10	4·80	4·01
41	61	25	44	23	39	1·56	1·64	17	16	16	3·81	4·20
42	52	21	37	19	33	1·58	1·56	14	13	13	4·00	3·46
43	46	19	34	17	30	1·53	1·59	19	17	18	2·56	3·66
44	53	22	36	18	32	1·66	1·64	13	12	12	4·42	3·63
45	43	18	28	14	25	1·72	1·82	12	11	11	3·91	4·17
46	46	19	25	13	22	2·09	2·12	12	11	11	4·18	4·97
47	41	17	18	9	16	2·56	1·99	7	6	6	6·83	7·67
48	24	10	20	10	18	1·33	1·63	2	2	2	12·00	7·34
49	16	7	18	9	16	1·00	1·48	5	5	5	3·20	6·48
50	17	7	9	5	8	2·12	1·54	4	4	4	4·25	4·48
51	12	5	9	5	8	1·50	2·21	2	2	2	6·00	7·42
52	12	5	5	3	4	3·00	2·08	1	1	1	12·00	8·33
53	7	3	4	2	4	1·75	3·25	1	1	1	7·00	9·67
54	10	4	2	1	2	5·00	2·58	1	1	1	10·00	—
55	4	2	4	2	4	1·00	2·67	—	—	—	—	—
56	4	2	2	1	2	2·00	3·33	—	—	—	—	—
57	7	3	1	1	1	7·00	3·00	—	—	—	—	—
58	—	—	1	1	1	0	2·44	2	2	2	0	—
59	1	0	3	1	3	0·33	—	1	1	1	1·00	—
60	1	0	—	—	—	—	—	—	—	—	—	—
61	1	0	1	1	1	1·00	—	—	—	—	—	—
62	—	—	1	1	1	0	—	—	—	—	—	—
64	1	0	—	—	—	—	—	—	—	—	—	—
Total...	2,418		1,940		1,724			1,084		1,006		

Table 5 c. Measurements of Plaice, Dabs and Haddock caught by Seiner "Primula" and Trawler "Platessa", 1946.

Species	Plaice				Dab				Haddock			
Ground	A				A				B			
Length in Cm.	"Primula"		"Platessa"		"Platessa"		"Primula"		"Primula"		"Platessa"	
	Number caught	‰	Number caught	‰	Number caught	‰	Number caught	‰	Number caught	‰	Number caught	‰
13	—	—	—	—	2	4	—	—	—	—	—	—
14	—	—	—	—	6	11	—	—	—	—	—	—
15	—	—	—	—	6	11	3	20	—	—	—	—
16	—	—	—	—	33	62	3	20	—	—	—	—
17	—	—	—	—	77	144	10	66	—	—	—	—
18	—	—	—	—	113	211	12	79	—	—	—	—
19	—	—	—	—	116	217	13	86	—	—	—	—
20	—	—	1	4	72	134	17	113	2	2	—	—
21	5	7	1	4	54	101	14	93	2	2	—	—
22	19	28	3	13	32	60	18	119	—			
23	30	44	8	35	13	24	25	166	1	1	1	3
24	50	74	12	52	8	15	18	119	9	10	—	—
25	64	95	16	70	2	4	8	53	34	36	8	21
26	62	92	11	48	—	—	3	20	100	107	22	58
27	72	107	18	79	—	—	4	26	147	158	49	130
28	73	108	21	92	—	—	—	—	160	172	58	154
29	54	80	15	66	—	—	2	13	147	158	71	189
30	43	64	18	79	—	—	—	—	79	85	48	128
31	38	56	13	57	1	2	1	7	32	34	15	40
32	35	52	12	53	—	—	—	—	16	17	9	24
33	29	43	17	74	—	—	—	—	12	13	4	11
34	41	61	27	118	—	—	—	—	16	17	10	26
35	17	25	15	66	—	—	—	—	23	25	13	35
36	13	19	7	31	—	—	—	—	25	27	11	29
37	11	16	1	4	—	—	—	—	22	24	10	26
38	4	6	4	17	—	—	—	—	20	22	14	37
39	5	7	4	17	—	—	—	—	34	36	8	21
40	3	5	3	13	—	—	—	—	21	23	6	16
41	2	3	—	—	—	—	—	—	10	11	7	19
42	—	—	1	4	—	—	—	—	6	6	3	8
43	—	—	—	—	—	—	—	—	4	4	7	19
44	1	1	—	—	—	—	—	—	2	2	1	3
45	—	—	—	—	—	—	—	—	2	2	—	—
46	—	—	—	—	—	—	—	—	3	3	1	3
47	1	1	—	—	—	—	—	—	1	1	—	—
50	2	3	—	—	—	—	—	—	1	1	—	—
51	—	—	—	—	—	—	—	—	1	1	—	—
54	—	—	1	4	—	—	—	—	—	—	—	—
57	2	3	—	—	—	—	—	—	—	—	—	—
Total...	676		229		535		151		932		376	

length caught by the seine to those caught by the trawl in the same fishing time, a curve very similar to that for dabs is obtained (Figure 2 (b)), the numbers less than 23 cm. being small. The similarity of the curves for plaice and dabs is almost certainly due to the similarity of those two species of fish. It would seem likely therefore, that, had there been more very small plaice on the fishing ground where the experiment was carried out, more marked differences between the length distribution curves of seine- and trawl-caught plaice would have been apparent over the smaller size ranges. The curve appears to reach an asymptote, the level of which will give the true ship-to-ship fishing factor.

The length distributions of seine- and trawl-caught haddock are similar to each other.

The differences between the lengths of flatfish caught by the two different gears are not due to differences in the manufactured cod-end mesh sizes, nor are they due to the inclusion of measurements made on board the trawlers at night when the seiner was not fishing. It is possible that the use of a cotton cod-end by "Arabis", as compared with the double strand sisal cod-end of the trawlers gave a different

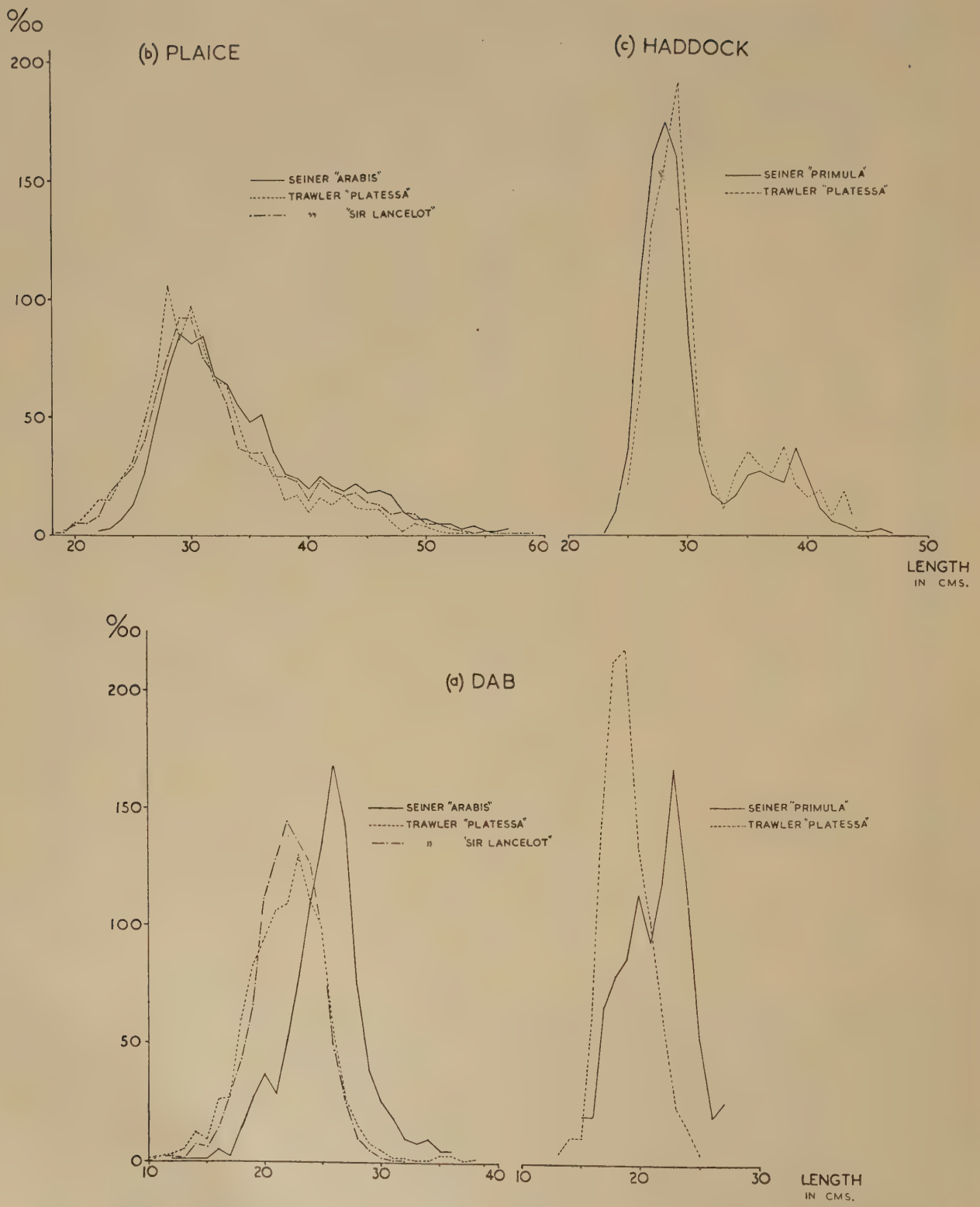

Figure 1. Length distribution of trawl- and seine-caught fish. (a) Dab. (b) Plaice. (c) Haddock.

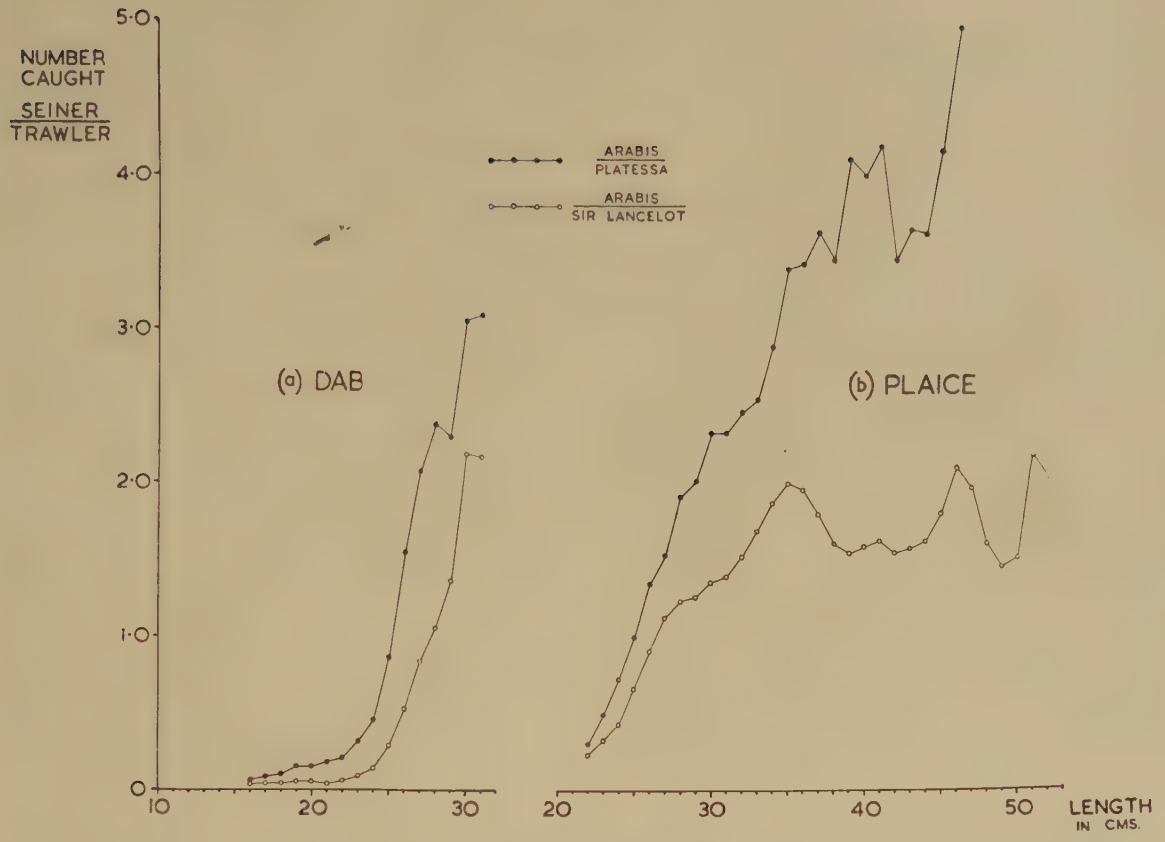

Figure 2. Ratios of numbers of of seine-caught to numbers of trawl-caught fish at each centimetre length. (a) Dab. (b) Plaice.

mesh selection effect, but the seiner "Primula" used a sisal cod-end similar to that used by the trawlers and still there was a difference in the size selection of dabs. Further, in experiments with trawls (1), no size selection differences were observed between the catches of plaice made with a hemp cod-end and those made with a sisal cod-end of the same mesh size. Different mesh selections due to different material in the cod-ends, if occurring at all, could scarcely have given rise to more than a small part of the observed differences in selection between the gears used in these experiments. A more likely, although perhaps additional, explanation of the size selection observed in these experiments is that selection is operated by the seine gear before the fish enter the net. The area swept by seine warps may be as much as 3,000 feet wide so that some fish might be driven about 1,500 feet by the warps before being picked up by the net. It seems likely that the warps would pass over some of the very small fish before they could reach the mouth of the net, while the larger fish would be able to keep in front of the moving warp and so be taken up by the net.

"Sir Lancelot" caught considerably more, and "Platessa" slightly more invertebrate "soil", consisting chiefly of starfish, than did "Arabis". The trawlers, especially "Sir Lancelot", caught far more *Cancer pagurus* than did the seiner and their catches included numbers of *Loligo* which was absent from the seiner's catches.

More plaice were bruised in the trawls than in the seine (Table 6). The index of presence or absence of pink coloration on the underside of the head was chosen as being a feature which could be easily and quickly noticed on board a commercial vessel. Among "Sir Lancelot"'s catches there were never less than 55%, frequently over 90%, and once 100% of the plaice bruised. The range of the proportion of bruised plaice in "Platessa"'s catches was between 7% and 61% in different hauls. There were frequently no

Table 6. Condition of Seine- and Trawl-caught Plaice.

Ship	Number Examined	Number Bruised.	% Bruised
"Arabis"	2993	44	1·5%
"Sir Lancelot"...	1992	1591	80%
"Platessa"	1564	537	34%

bruised plaice in hauls made by "Arabis" and the maximum proportion of fish bruised in any one haul was 3%. Furthermore, the bruising of individual fish was more severe in the trawl than in the seine.

Discussion and Conclusions.

(1) It is apparent that, given certain conditions, a seiner can outfish a trawler on both plaice and haddock. Assuming the spread between otter boards of "Platessa"s trawl to be 50 ft., then the area of ground swept by the trawl during a haul of 3 hours duration will be about 60,000 square fathoms. The area swept by the seine net alone, when working with 1100 fm. warps, cannot be greater than, and will certainly be considerably less than 20,000 sq. fm. The area surrounded by the warps and net in any one haul will be about 200,000 sq. fm. Thus, the area fished in $1^1/_4$ hours will be more than three times as large as that fished by the trawler in 3 hours. The ratio of areas covered per 24 hours at the equinox, "Arabis" : "Platessa", will be about 3·2 : 1, which is closely similar to the figure of 2·8 : 1 for the ratio of comparable catches of plaice.

(2) Present evidence indicates that the sizes of haddock caught in both the seine and the trawl are the same when the nets are fitted with cod-ends of the same mesh size, but that there are differences between the two types of gear in their selection of dabs and, most probably, also of plaice. The trawl took relatively more and the seine less of the small dabs. A similar differential selection of plaice is apparent and probably would have been more so had there been more small plaice on the fishing ground where the experiment was carried out. It is suggested that this differential selection, which seems to operate over a range of small fish of length below about 30 cm., does so before the fish enter the net, probably by the warps passing over some of the smaller fish before they can be driven into the area to be swept by the net.

(3) The seine is not efficient in catching soles.

(4) Very few plaice are damaged in the seine. In the trawl, under similar weather conditions, almost the entire catch of plaice may be damaged.

(5) The greater catches of a seiner are achieved with greater economy of engine fuel and manpower than are the smaller catches of a trawler.

(6) Seining is more restricted to certain grounds by the nature of the bottom than is trawling. It is also restricted by strong tides on some grounds at certain times.

References.

(1) Margetts, A. R. "Experimental Comparison of Fishing Capacities of Different Trawlers and Trawls". This volume, preceding paper.

7.

Fishing Capacities of Gears used by English and Scottish Research Vessels.

By

B. B. Parrish

In order that the fishing data obtained from countries using different types of vessel and gear in the North Sea could be better co-ordinated, the Southern North Sea Area Committee incorporated inter-ship fishing tests as part of its 1947 programme. This report deals with one such test carried out between the English research vessel "Sir Lancelot" and the Scottish research vessel "Explorer" on a roundfish ground off the Berwickshire coast in December 1947.

A series of hauls, each of three hours' duration, was made by each vessel over the same ground, marked by dhans, and the catch of fish of each was sorted into species, counted, measured and weighed. Records of the invertebrates caught, damage to gear and other details were also taken. Communication was maintained between the ships at frequent intervals throughout the course of the experiment.

Description of Vessels and Gear.

The details below show that the nets used by the two vessels differed in a number of important characteristics. In addition to the difference in catching capacity caused by the use by one of the V.D. gear, the dimensions of the upper parts of the nets showed striking differences which might result in distinctive catching powers. The "Explorer"s net was characterized by long upper wings and small square, which, together with the longer headline, allowed for greater spread than was possible in that of the "Sir Lancelot" which had smaller upper wings and larger square. Also, the relative dimensions of the upper and lower sides differed in the two nets. In that of the "Explorer", the upper wings plus square were of equal length to the ground-rope, so that very little slack would be allowed in the top of the net when towing. In that of the "Sir Lancelot", however, the upper wings plus square length was 12 feet greater than that of the ground-rope, thus allowing greater freedom of movement of the top of the net during towing.

Experimental Data.

Fifteen hauls were made by each vessel during the course of the experiment but of these only seven gave comparable results. The working data for each haul,

Type of Vessel and Gear used during the Experiment:

"Sir Lancelot"

125 ft. steam trawler with Gourock Lt. No. 4. Otter Trawl using V.D. gear with 30 fathom bridles. 24 floats on headline. No bobbins or tickler chain.

"Explorer"

149 ft. Standard Mersey Class Trawler using long-winged Otter Trawl without V.D. gear. No floats on headline and no bobbins or tickler chain.

The Dimensions of the Parts of the two Nets.

Part of Net	Length in Feet "Explorer"	Length in Feet "Sir Lancelot"	Size of Mesh "Explorer"	Size of Mesh "Sir Lancelot"
Upper Side of Net				
Wings	43	32	$5^1/_2$ ins.	6 ins.
Square.....	15	28	$5^1/_2$ -	6 -
Baitings.....	27	30	$5\text{-}3^1/_2$ -	$5\text{-}4^1/_2$ -
Cod-End	25	21	80 mm.	80 mm.
Head-Rope ..	112	80	—	—
Lower Side of Net				
Wings	63	66	$5^1/_2$ ins.	5 ins.
Belly	28	30	$5\text{-}3^1/_2$ -	$5\text{-}4^1/_2$ -
Cod-End	25	21	80 mm.	80 mm.
Ground-Rope	58	48	—	—
Bosom.....	22	20	—	—

Both trawls were of sisal 3 ply, with double twine in the cod-ends. "Explorer"s net tarred; "Sir Lancelot"s untarred.

Table 1. Working Data for Comparative Trawling Experiment.

Haul No.	Position	Date	Duration	Depth in Fathoms	Remarks	
					Explorer	Sir Lancelot
1	54°51′ N. 0°40′ W.	3-12-47	2 hours	32—36	Clear haul	Entire net torn from headline
2	54°55′ N. 0°42′ W.	4-12-47	40 min.	39	—	Entire net torn from headline
3	55°57′ N. 1°30′ W.	4/5-12-47	3 hours	42	—	Clear haul
4	— —	5-12-47	3 —	42	—	—
5	— —	—	3 —	42	Belly and wings of trawl split	—
6	56°02′ N. 1°30′ W.	—	3 —	32—50	Clear haul	—
7	— —	8-12-47	3 —	—	—	—
8	— —	8/9-12-47	3 —	—	—	—
9	— —	9-12-47	3 —	—	—	Upper wing badly torn
10	— —	—	3 —	—	—	Foul haul
11	— —	—	3 —	—	—	Belly and wings torn
12	— —	10-12-47	3 —	—	—	Clear haul
13	— —	—	3 —	—	—	—
14	— —	—	25 min.	—	Large boulder in trawl split	Belly and wings torn
15	— —	—	1½ hours	—	Belly of net split	— — — —

together with details of damage to gear, are given in Table 1. It is seen from the table that the "Sir Lancelot"s net suffered damage on six occasions and the "Explorer"s on three, and the "Sir Lancelot"s foul hauled once. This high incidence of damaged gear caused a change of trawling ground on two occasions, but in each case a ground was chosen which was known to be frequently fished by North Sea trawlers and which was outside the rough ground area. It is evident, however, that the ground was of a stony nature, with the result that the net with the deeper "bite" suffered greater damage. The splits in the "Sir Lancelot"s gear in hauls 1 and 2 were of too serious a nature to be attributed to the stony bottom and were probably caused by major obstructions, probably wrecks, but in all the others they were not discovered until after the net was hauled at the end of the trawling period, and were therefore probably caused by the irregularities of the bottom. Hauls 3, 4, 6, 7, 8, 12 and 13 yielded comparable data, and these have been used in the subsequent analysis.

Composition of Catches by Weight and Number.

The weight and number, and percentage composition of the catches of each vessel for each of the main species of fish for the seven comparable hauls are given in Tables 2 and 3. Also, the total weight of each species caught by the two vessels is plotted in Fig. 1. Separate figures are given for flatfish, cod, haddock, whiting, angler and skates, but other species, which were of less frequent occurrence, are recorded together as miscellaneous.

It is evident that, despite wide fluctuations in the catches of each species from haul to haul, there were marked differences in the relative numbers and weights of the main species in the catches of the two vessels. This is shown by the following figures, which represent the ratios "Explorer" catch/"Sir Lancelot" catch, by number and weight for each species caught in the seven hauls.

	Ratio by Number	Ratio by Weight
Flatfish	0·9 : 1	0·57 : 1
Cod	0·83 : 1	0·86 : 1
Haddock	2·65 : 1	1·96 : 1
Whiting	19·6 : 1	
Angler	0·49 : 1	0·53 : 1
Skate and Ray	0·08 : 1	0·16 : 1
All Fish	1·90 : 1	1·16 : 1

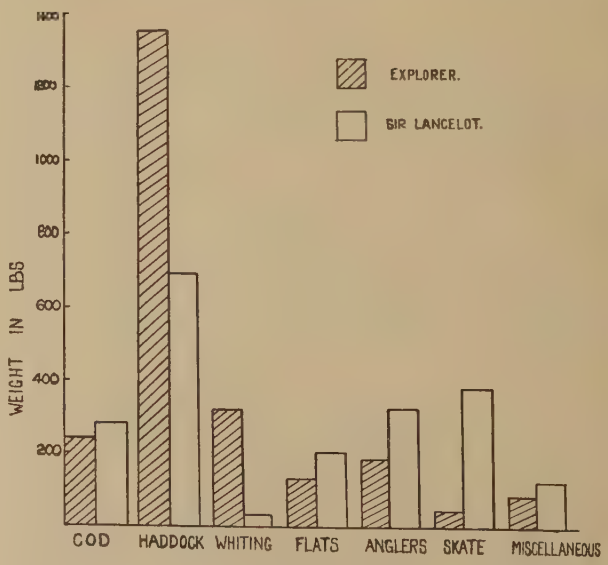

Figure 1. Weight of each species caught by "Explorer" and "Sir Lancelot" in selected hauls.

Table 2. Composition of Catches of Each Ship by Number for Each Species.

Haul No.	Flats				Cod				Haddock				Whiting			
	Explorer		Sir Lancelot		Explorer		Sir Lancelot		Explorer		Sir Lancelot		Explorer		Sir Lancelot	
	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%
3.....	9	6·0	3	3·8	2	1·3	2	2·5	31	20·9	8	10·2	96	64·4	3	3·8
4.....	12	5·1	10	13·0	2	0·9	3	3·9	88	37·4	15	19·5	103	43·8	1	1·3
6.....	34	8·2	69	20·5	38	9·2	28	8·3	282	68·3	158	46·7	24	5·8	2	0·6
7.....	30	15·8	9	6·5	—	—	3	2·2	103	54·1	44	31·6	43	22·7	4	2·9
8.....	47	8·5	38	20·1	11	2·0	9	4·8	405	73·8	72	38·0	68	12·4	3	1·6
12.....	18	4·0	44	16·6	10	2·2	21	7·9	290	65·0	168	63·0	110	24·6	9	3·4
13.....	53	12·5	52	25·2	2	0·5	12	5·8	248	58·7	82	39·9	103	24·7	6	2·9
All Hauls	203	8·4	225	17·4	65	2·7	78	6·0	1447	60·2	547	42·3	547	22·7	28	2·2

Haul No.	Angler				Skate-Ray				Miscellaneous				Total Fish			
	Explorer		Sir Lancelot		Explorer		Sir Lancelot		Explorer		Sir Lancelot		Explorer		Sir Lancelot	
	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%	No. of Fish	%
3.....	5	3·4	14	17·7	—	—	48	60·7	6	4·0	1	1·3	149	100	79	100
4.....	9	3·8	18	23·4	7	3·0	27	35·0	14	6·0	3	3·9	235	100	77	100
6.....	7	1·7	16	4·7	—	—	19	5·6	28	6·8	46	13·6	413	100	338	100
7.....	9	4·7	14	10·0	2	1·1	61	43·9	3	1·6	4	2·9	190	100	139	100
8.....	6	1·1	12	6·4	8	1·5	51	27·0	4	0·7	4	2·1	549	100	189	100
12.....	5	1·1	4	1·5	1	0·2	2	0·8	13	2·9	18	6·8	447	100	266	100
13.....	7	1·7	19	9·2	1	0·2	24	11·6	9	2·1	11	5·4	423	100	206	100
All Hauls	48	2·0	97	7·5	19	0·8	232	17·9	77	3·2	87	6·7	2406	100	1294	100

Thus, the "Explorer" caught more haddock and whiting, and the "Sir Lancelot" more of the bottom-living forms, such as anglers, skates and rays and flatfish. When the average catch of each species is calculated for each vessel, it is found that those for whiting, angler and skate and ray are significantly different at the 5 per cent. point for the seven hauls, and for haddock if hauls 3 and 4, which were smaller than the remainder, are neglected. No significance, however, can be attached to the observed differences in the average catches of other species, or the total catch.

Size Composition of Catches.

The above ratios for haddock show that the difference between the catches of the two vessels was greater by numbers than by weight of fish caught, which points to a greater number of the smaller sizes in the "Explorer"s catches. Therefore, in order to gauge the difference in size composition between the two sets of data, the haddock catches have been analysed in centimetre size categories, and the ratio of numbers at each length determined. The size distribution for each haul, and that for the total catch of each vessel, are given in Table 4, and the number at each centimetre length for the smoothed data, together with the corresponding ratios of numbers at each size, are plotted in Fig. 2.

The analysis shows that the "Explorer" caught significantly more haddock less than 40 centimetres in length, whereas above this size no significance could be attached to the observed differences. Furthermore, the difference in numbers at each length was not constant over the smaller sizes. The maximum difference was observed between 32—35 centimetres, at which length the "Explorer" caught approximately four times more fish than did the "Sir Lancelot". This peak corresponded with the mode of the total size distribution.

The numbers of other species in the total catch of each vessel were too small for detailed analyses of the size compositions to be carried out, but for whiting and flatfish, the "Sir Lancelot" caught less of the smaller sizes in proportion to the total catch than did the "Explorer".

Catch of Invertebrates.

Data relating to the number of invertebrates caught in each haul by each vessel are given in Table 5. Only those species which were of frequent occurrence in one or other of the vessels' catches are included.

Table 3. Composition of Catches of Each Ship by Weight for Each Species.

Haul No.	Flats				Cod				Haddock				Whiting			
	Explorer		Sir Lancelot		Explorer		Sir Lancelot		Explorer		Sir Lancelot		Explorer		Sir Lancelot	
	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	weight in lbs.	%	Weight in lbs.	%
3.....	4	3·5	3	2·1	2	1·7	1	0·6	35	30·9	16	11·2	49	43·2	—	—
4.....	11	5·5	9	7·1	3	1·5	6	4·7	82	41·3	23	18·1	58	29·1	—	—
6.....	22	3·9	44	8·8	156	27·9	108	21·8	309	55·1	212	42·6	20	3·6	—	—
7.....	12	6·0	8	3·1	—	—	[1])	—	96	47·7	54	20·8	24	11·9	[1])	—
8.....	24	4·8	44	15·8	30	6·0	[1])	—	362	72·8	88	31·7	51	10·1	[1])	—
12.....	20	4·8	32	8·5	41	9·8	100	26·6	269	64·0	212	56·4	62	14·8	[1])	—
13.....	19	6·0	56	18·6	3	1·0	58	19·2	207	66·0	87	28·8	56	17·8	[1])	—
All Hauls	112	4·9	196	9·9	235	10·2	273	13·8	1360	58·9	692	34·8	320	13·9	[1])	—

Haul No.	Angler				Skate-Ray				Miscellaneous				Total Fish			
	Explorer		Sir Lancelot		Explorer		Sir Lancelot		Explorer		Sir Lancelot		Explorer		Sir Lancelot	
	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%	Weight in lbs.	%
3.....	20	17·6	54	37·7	—	—	67	47·0	4	3·1	2	1·4	114	100	143	100
4.....	26	13·1	43	33·8	14	7·0	36	28·4	5	2·5	10	7·9	199	100	127	100
6.....	24	4·3	65	13·0	—	—	31	6·2	29	5·2	38	7·6	560	100	498	100
7.....	44	21·9	40	15·4	14	7·0	134	51·8	11	5·5	23	8·9	201	100	259	100
8.....	18	3·6	44	15·8	10	2·0	82	29·5	4	0·7	20	7·2	499	100	278	100
12.....	16	3·8	14	3·7	—	—	3	0·8	12	2·8	15	4·0	420	100	376	100
13.....	24	7·6	65	21·5	2	0·6	24	7·9	3	1·0	12	4·0	314	100	302	100
All Hauls	172	7·5	325	16·4	40	1·7	377	19·0	68	2·9	120	6·1	2307	100	1983	100

[1]) A small number present, weighed with miscellaneous.

It is seen from the table that, despite the lack of data for two of the "Sir Lancelot"s hauls, this ship caught greater quantities of the large invertebrates than did the "Explorer", especially those species which are truly benthonic, such as *Modiola* and anemones.

Differences in Trawl Behaviour.

It is evident from the results that the two trawls differed markedly in their capacity to catch and retain different species of fish and to fish the ground closer without damage to gear. Two striking differences in behaviour present themselves; firstly, the apparently deeper "bite" of the "Sir Lancelot" net as shown by the higher incidence of splits and greater catch of the bottom-living fish and invertebrates, and secondly, the greater capacity of the "Explorer"s net to catch and retain haddock and whiting. These may be analysed in the light of the differences in dimension and structure of the two trawls.

The deep "bite" of the "Sir Lancelot"s gear, which is customary with southern North Sea trawlers fishing for flatfish on smooth ground, can be attributed

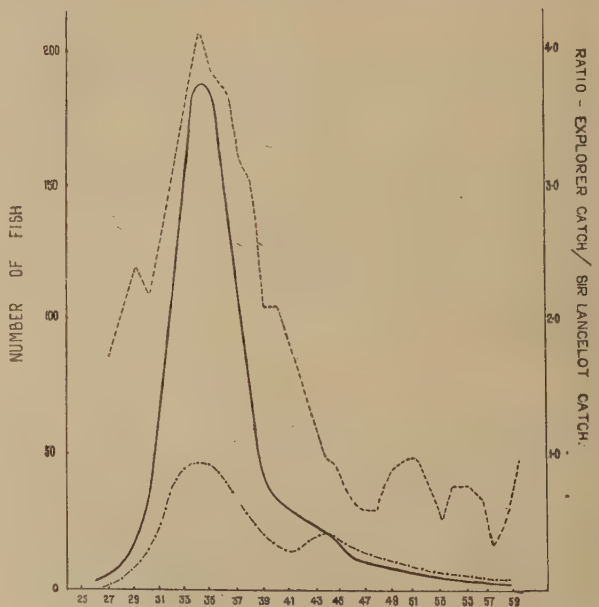

Figure 2. Size distribution of haddock caught by "Explorer" and "Sir Lancelot", and ratio of numbers at each centimetre length. — (Figures smoothed in 3's.)

Table 4. Length Distribution of Haddock Caught by "Explorer" and "Sir Lancelot", and Ratio of Numbers at Each Centimetre Increase in Size.

Length in Cm.	Haul No. 3		Haul No. 4		Haul No. 6		Haul No. 7		Haul No. 8		Haul No. 12		Haul No. 13		All Hauls		Smoothed in 3's		Ratio Explorer Catch
	Expl.	Sir L.	Expl.	Sir L.	Expl.	Sir L.	Expl.	Sir L.	Expl.	Sir L.	Expl.	Sir L.	Expl.	Sir L.	Expl.	Sir L.	Expl.	Sir L.	Sir L.
24....	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—
25....	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	2	—	—
26....	—	—	—	—	1	—	—	—	1	1	—	—	1	1	3	2	3	—	—
27....	—	—	—	—	—	—	1	—	2	—	—	1	3	—	6	1	7	4	1·8
28....	—	—	—	—	1	1	3	2	2	—	2	4	4	1	12	8	20	8	2·5
29....	—	—	2	—	4	1	2	2	11	1	13	8	9	4	41	16	37	16	2·3
30....	—	—	2	—	11	2	2	2	9	3	11	12	23	4	58	23	80	29	2·8
31....	2	1	14	—	27	11	6	5	39	1	34	17	20	13	142	48	129	39	3·3
32....	3	—	11	—	18	12	19	5	70	10	36	11	31	9	188	47	180	47	3·8
33....	3	1	18	2	41	10	16	4	52	7	43	12	36	9	209	45	197	45	4·4
34....	4	—	7	1	27	10	18	4	64	6	35	12	39	13	194	46	189	47	4·0
35....	3	—	8	2	27	21	9	3	47	6	39	14	27	4	160	50	155	40	3·9
36....	2	—	6	—	31	10	5	1	27	5	18	6	20	1	109	23	112	33	3·4
37....	—	—	3	—	18	11	1	4	24	3	11	5	8	4	65	27	73	23	3·2
38....	4	—	2	1	17	6	4	—	12	3	3	8	3	1	45	19	48	22	2·2
39....	2	—	2	1	9	4	2	1	8	8	5	4	7	1	35	19	33	15	2·2
40....	—	—	—	—	1	2	2	1	6	—	5	3	4	—	18	6	30	14	2·1
41....	1	—	4	—	8	7	4	—	6	1	10	9	3	—	36	17	25	14	1·8
42....	—	—	2	—	4	7	2	1	7	4	7	4	—	4	22	20	27	20	1·4
43....	2	—	1	1	7	10	—	1	6	3	7	6	1	2	24	23	20	20	1·0
44....	1	1	3	2	1	8	1	—	2	3	4	2	3	—	15	16	15	17	0·9
45....	—	1	1	—	4	3	—	—	1	2	1	4	—	—	7	10	10	15	0·7
46....	1	1	1	2	5	6	1	2	—	—	1	6	—	2	9	19	7	13	0·6
47....	—	—	—	1	1	2	—	1	3	1	—	3	2	1	6	9	8	14	0·6
48....	3	—	—	1	2	5	1	1	2	1	—	4	1	2	9	14	8	9	0·9
49....	—	—	1	—	6	1	—	—	—	1	1	1	—	2	8	5	8	8	1·0
50....	—	1	—	—	3	2	—	1	1	1	1	1	2	—	7	6	6	6	1·0
51....	—	1	—	—	2	2	—	1	—	—	—	1	—	1	2	6	4	6	0·7
52....	—	1	—	—	1	1	1	1	—	—	1	1	1	1	4	5	3	6	0·5
53....	—	—	—	—	—	2	1	1	1	—	1	3	—	—	3	6	3	4	0·8
54....	—	—	—	—	2	—	—	—	—	1	1	—	—	1	3	2	3	4	0·8
55....	—	—	—	1	2	—	—	—	—	—	—	1	—	1	2	3	2	3	0·7
56....	—	—	—	—	1	—	—	—	—	—	—	3	—	—	1	3	1	3	0·3
57....	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	2	1	2	0·5
58....	—	—	—	—	—	—	1	—	—	—	—	—	—	—	1	—	1	1	1·0
59....	—	—	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—	—	—
60....	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	—
Total.	31	8	88	15	282	158	103	44	405	72	290	168	248	82	1447	547	1447	547	

to the weight of the 30 fathom bridles acting at ground level through the ground-ropes which took the full towing strain.

The "Explorer"s net on the other hand had no V.D. gear, the net being attached to the trawl boards directly so that less weight would be concentrated at ground level.

The greater capacity of the "Explorer"s net to catch and retain haddock and whiting is more difficult to associate with particular differences in trawl structure, since a number of possible contributory factors were involved. Its greater headline and upper wing length gave it a greater spread than the "Sir Lancelot"s and although no accurate measures of the difference in spread of the two nets were made, this factor would contribute in some measure to its greater roundfish catch. It is evident, however, that for both haddock and whiting—especially whiting—headline length alone could not explain the difference in the catch of the two vessels. This is illustrated by the following figures which give the numbers of both species in the two vessels' catches, when those for the "Sir Lancelot" have been multiplied by the headline length ratio of 1·4.

Table 5. Numbers of Invertebrates in the Trawl Catches of "Explorer" and "Sir Lancelot".

Haul No.	*Modiola*		Anemones		*Echinus esculentus*		*Cancer pagurus*		*Loligo*	
	Explorer	Sir Lancelot	Explorer	Sir Lancelot	Explorer	Sir Lancelot	Explorer	Sir Lancelot	Explorer	Sir Lancelot
3	—	Many	6	Many	—	1	—	11	—	—
4	2	No data	1	No data	—	No data	2	No data	—	No data
6	—	No data	3	No data	1	No data	?	No data	25	No data
7	2	90	6	Many	—	—	1	6	—	6
8	9	100	12	Many	—	3	—	16	—	4
12	4	1	—	—	14	34	—	1	—	10
13	1	3	2	12	5	22	—	2	6	8

Haul	"Explorer" Untreated Data		"Sir Lancelot" Raised by factor 1·4		Ratio "Explorer" catch/ "Sir Lancelot" catch	
	Haddock	Whiting	Haddock	Whiting	Haddock	Whiting
3.....	31	96	11	4	2·81:1	24·0:1
4.....	88	103	21	1	4·2 :1	103·0:1
6.....	282	24	221	3	1·28:1	8·0:1
7.....	103	43	62	6	1·66:1	7·2:1
8.....	405	68	100	4	4·05:1	17·0:1
12.....	290	110	235	13	1·24:1	8·5:1
13.....	248	103	115	8	2·16:1	12·9:1
Total ..	1447	547	765	39	1·89:1	14·0:1

Thus the treated data for the "Sir Lancelot"s catches are still lower than those for the "Explorer".

It has been stated previously that the two nets differed in the amount of freedom of movement allowed in the tops. In the "Explorer"s the top wings plus square length was equal to that of the ground-rope, whereas in the "Sir Lancelot"s there was twelve feet of slack in the top of the net. It is probable therefore that the square of the "Sir Lancelot"s net would experience greater vertical movement during towing and would maintain a fully opened mesh due to the pressure of water acting upon it, so that fish entering it would have greater freedom to escape through the square than would those entering that of the "Explorer". Under these conditions the greatest number of escapes would be expected to occur at the modal point of the size distribution of the population; that is, if fish at this size could escape with equal ease to those of smaller size. This was the case in this experiment so that the relative dimensions of the top and bottom of the two nets may have contributed in some measure to the difference in their capacity to catch haddock and whiting. It must be borne in mind, however, that the height of the headline from the ground may have differed in the two nets, a factor which would also contribute to the difference in the catch of the more active roundfish such as haddock and whiting; but no measurements of this variable were taken during the experiment.

Summary.

The above analysis is based on the data collected during an inter-ship trawling test between the English and Scottish research vessels in December 1947. Fifteen hauls, of which seven gave comparable results, were made and the catches recorded by number and weight.

The following main differences between the fishing capacities of the two vessels were established.

1) The "Explorer"s net caught significantly more whiting and haddock, but significantly less anglers and skates than did the "Sir Lancelot"s;

2) The difference in the numbers of haddock caught by the two ships was confined to sizes less than 40 centimetres in length. Above this size, no significant difference could be established between the numbers;

3) The "Sir Lancelot"s gear sustained a higher incidence of damage, and picked up a greater quantity of invertebrates.

These results were then analysed in the light of the structural and dimensional characteristics of the two ships' gears, and the conclusion drawn that the difference in the dimensions of the upper and lower sides of the two nets could explain, at least in part, the differences in catching capacity for different species of fish.